



Ontario Hydro



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**DARLINGTON NGS PREOPERATIONAL
AQUATIC STUDY - 1984**

Report No. 87-82-K

J.S. Griffiths
Biologist
Biological Research Section
Chemical Research Department

ABSTRACT

During the first year of preoperational aquatic studies at Darlington, alewife numerically dominated the gill net catch (83.9%). Of the cold water species (6.2% = 688 fish), round whitefish was the most abundant, followed by lake trout, brown trout, rainbow trout and coho salmon. Alewife abundance was high from May to July, declining sharply after October. Round whitefish numbers peaked during the December spawning period. Lake trout, brown trout and rainbow trout numbers peaked in November, while coho salmon were abundant only in October. Average alewife catches were lower in the diffuser area than in reference areas east and west of Darlington. Lake trout catches were highest at the east reference site. Round whitefish average catches were similar for the diffuser and reference areas, but the largest single-net catch (36 fish) was taken at the diffuser. Round whitefish fecundities ranged from 3600 eggs/female for fish aged 4+ to 19 800 for fish aged 9+. The average fecundity (age 5+) was 6900 eggs. Twelve substrate sites were inspected to provide baseline data on movement of sediments. Some sand was observed at nine sites, but consistently only at three sites. Procedural problems may have contributed to apparent movement of sand. However, observations suggest that the sand is quite mobile and substantial accumulations exist east of Darlington.

job	34-136-492	file	837.321 DAR	date	March 20, 1987	report no.	87-82-K
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EXECUTIVE SUMMARY

DARLINGTON NGS PREOPERATIONAL AQUATIC STUDY - 1984

J.S. Griffiths
Biologist
Biological Research Section
Chemical Research Department

This report describes results for the first year of preoperational aquatic studies at Darlington. Objectives for this year were to monitor the relative abundance and species composition of juvenile and adult fish, especially spawning cold water species, to obtain fecundity estimates for spawning round whitefish, and to obtain baseline information for evaluation of sediment movement effects on spawning habitats.

Juvenile and adult fish were monitored in 110 gill net sets over the May to December period, yielding a total catch of 11 180 fish. Alewife numerically dominated the catch (83.9%), followed by smelt (7.6%). Of the cold water species (6.2% = 688 fish), round whitefish was the most abundant (237), followed by lake trout (190), brown trout (124), rainbow trout (85) and coho salmon (52).

Alewife abundance was highest in the May to July period and declined sharply after October. Smelt were abundant in May. Round whitefish numbers increased during the fall and peaked during the December spawning period. Lake trout, brown trout and rainbow trout numbers peaked in November, while coho salmon were abundant only in October.

Average alewife catches were lower in the diffuser area than in reference areas east and west of Darlington, although the data were highly variable. Lake trout and alewife catches were highest at the east reference site, but peak abundances occurred at different times of the year. Round whitefish average catches

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were similar for the diffuser and reference areas, but the largest single-net catch (36 fish) was taken at the inshore end of the diffuser in December.

Round whitefish fecundities ranged from 3600 eggs/female for fish aged 4+ to 19 800 for fish aged 9+ years. Catch data suggest an average age for the spawning population of 5+, yielding a fecundity of 6900 eggs/female. Growth data obtained from 200 round whitefish aged in 1984 appear similar to previous results for Lake Ontario fish.

Twelve substrate sites selected to provide baseline information on movement of sediments (which may adversely affect incubating fish eggs) were inspected in October and November, 1984. A third inspection scheduled for the spring of 1985 was not completed until September/85. Sand appeared to be the substrate material most likely to be shifted by lake currents or storms. Some sand was observed at nine sites, but consistently only at three sites. Procedural problems may have contributed to apparent movement of sand at some sites, and new procedures should improve future results. However, recent (1985) observations suggest that sand in the area is quite mobile. As substantial accumulations of sand exist to the east of Darlington, large-scale sand movement into the study area appears possible during storms.

1984
Aug

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ontario hydro research division

To Mr. C.W. Dawson
Environmental Studies
and Assessments Dept
Design & Development - Generation

DARLINGTON NGS PREOPERATIONAL AQUATIC STUDY - 1984

1.0 INTRODUCTION

Darlington Nuclear Generating Station has been under construction since 1977. When completed, the station will consist of four 850 MW capacity CANDU reactors. Unit 2 is scheduled to go critical in May, 1987 and should become operational in May of 1988. Units 1, 3 and 4 are scheduled to start operation in 1989, 1991 and 1992, respectively. Condenser cooling water will be drawn from a depth of approximately 10 m and discharged offshore at a maximum flow rate of 150 m³/s. Darlington NGS will incorporate two design features which are unique among Ontario Hydro generating stations: a precast porous bottom (PPB) intake and a submerged offshore diffuser discharge.

The Environmental Studies and Assessments Department of Design and Development Division requested the undertaking of an initial aquatic study during 1984. This study forms part of an overall environmental monitoring program (Ontario Hydro Design & Development Division Report No 84252) consisting of three years of preoperational studies (1984-1986), six years of commissioning studies (1987-1992) and three years of postoperational studies (1993-1995). The development of specific aquatic monitoring tasks was based upon three principal objectives:

1. To detect and quantify major, long-term changes in aquatic biota in the vicinity of Darlington NGS which have resulted from construction and operation of the station.
2. To assist in the assessment of local and temporary changes in aquatic biota resulting from the marine construction of Darlington NGS facilities.

3. To assist in the measurement of effects from the cooling water system with particular emphasis on the environmental protection features incorporated into the design of Darlington NGS.

Table 1 provides a summary of the main components of the overall aquatic monitoring program from 1984 to 1995. This summary does not include studies that may be required to assess the effectiveness of various engineering systems, such as a fish handling system, if one is installed in the future.

The program has been designed to include consideration of several hypotheses of the effects resulting from operation of Darlington. These hypotheses were developed at the Darlington Aquatic Studies Workshop (Greig et al, 1984) and are stated as follows:

1. Displacement of benthic invertebrates and demersal fish larvae into offshore surface waters may result from diffuser entrainment if a significant portion of benthic organisms are suspended by currents around the diffuser.
2. Mortality of larval fish entrained into the cooling water system may result in long-term reductions in fish populations if a significant portion of the larvae are entrained.
3. Discharges of warm water from the diffuser may lead to reductions in round whitefish, lake whitefish and lake trout populations by effecting changes in survival of eggs and larvae if egg mortality rates increase significantly or advanced hatch results in asynchrony with the food supply for a significant portion of the larvae.
4. The presence of an offshore diffuser may lead to reductions in walleye, trout and salmon populations due to increased angler harvest if a significant portion of local game fish stocks remain in the diffuser area for extended periods.

Objectives of the 1984 Aquatic Study

The specific objectives of the 1984 preoperational study were:

- a) to monitor the relative abundance and species composition of juvenile and adult fish in the vicinity of Darlington with emphasis on spawning activity of cold water species,
- b) to obtain fecundity estimates for spawning round whitefish,

TABLE 1
PRELIMINARY SUMMARY OF PROPOSED MULTYEARE AQUATIC WORK

OBJECTIVE	PARAMETER	SPECIFIC PURPOSE	SAMPLING METHOD	SAMPLING FREQUENCY		SAMPLING LOCATIONS
				WITHIN YEAR	BETWEEN YEAR	
1. To detect and quantify major changes in aquatic biota resulting from the operation of Darlington MCS.	Substrate monitoring	To measure the effects of bedload shift on fish spawning habitats.	Diver observation, photography, rod measurements.	Approximately quarterly or clustered around major storm events.	Once in preop phase (1985/86), once in postop phase.	Two 1 m selected areas 10 m in diameter. Between 3 m and 12 m depth contours in and out of mixing zone.
	Predation by pelagic fish. (High variability may occur)	To characterize predation by pelagic fish on demersal fish larvae and benthic invertebrates and detect diffuser entrainment effects.	Analysis of stomach contents of pelagic fish from mixing zone. Fish collected by small purse seine or lift-net.	Once in each of May, July and September. 30 fish (smelt or alewife) to be collected each month. (Samples are for fish with food in stomachs).	Annual from 1985-1994.	Mixing zone vicinity and a location outside of the influence of the thermal outfall.
	Density of fish eggs and larvae. (Between year quantitative comparisons may not be possible.)	To estimate densities of fish eggs and larvae relative to entrainment, with a view towards assessment of reproductive success of cold-water species in mixing zone.	(i) Benthic sled conical plankton net tows, parallel to contours. (ii) Suction Pump (for eggs)	(i) Twice weekly in April and May (ii) Once in December	(i) Annual from 1985-1994 (ii) As above	(i) Along 3 transects centred on the mixing zone and 5 transects adjacent to intake. Plankton tows made at surface, mid-depth and near bottom. Sampling at approximately 5, 7, 10, 12, and 15 m contours. (ii) Selected areas.
	Adult and juvenile fish abundance.	To detect major changes in relative abundance of fish mixing zone, with emphasis on spawning activity.	(i) Gill Nets (ii) Acoustic Census (including some vertical gill net sets).	(i) Once in December and twice in May, July, October and November. (ii) Once in May, July and November (day and night).	(i) Annual in preop, commissioning and postop phases. (ii) Twice in preop phase (1985 and 1986), and once during 2 unit and 4 unit operation	(i) Along 3 transects: diffuser line, Port Darlington and McLaughlin Bay. Surface and bottom sets. (ii) Within 11-transect grids situated on diffuser line/ intake area and off Port Darlington. Transects perpendicular to shore (5-15 m depth contours).
2. To assess local and temporary changes in aquatic biota resulting from marine construction of Darlington MCS structures.	Sedimentation	To monitor the extent and duration of sedimentation resulting from intake excavation.	Sediment tubes on lake bottom, diver observation, photography, rod measurements.	Collection of tubes monthly from April to November.	During 1985	Within 2 grids (1 ha ² each) centred on excavation and dumping areas, at approximately 50 m intervals.
	Blasting mortality	To assess the mortality of fish due to underwater blasting	In situ test cages for eggs, larvae and adult fish. Lift-nets.	Selected underwater blasts in June, August and October.	During 1985	Selected intervals from blast centre.
3. To determine the effectiveness of environmental protection features incorporated in the design of Darlington MCS.	Diffuser effects.	To assess the response of fish populations to the operation of the diffuser.	(i) Gill nets (ii) Acoustic census	(i) Once in January to supplement regular fishing. (ii) As above.	(i) Once during preop phase (1986-7) and once during 2 unit and 4 unit operation. (ii) As above.	As indicated above for regular fishing.
	Cooling water intake effects: (a) Entrapment*	To assess the performance of the intake in diverting fish from entrapment. Assessment of fish abundance and behaviour near intake.	(i) A fixed, continuously recording sonar scanner. (ii) Diver observation, underwater video.	Once in May, August, November and January.	Once during preop phase (1985/6 or 7), and once during 2 unit and 4 unit operation.	Intake area.
	(b) Entrainment**	To assess rates of larval fish and zooplankton entrainment in relation to observed lake densities near the intake.	Plankton nets.	Twice weekly from April to August.	Once during preop phase (1985 or 6), and during 2 unit and 4 unit operation.	In forebay and near intake (depth-stratified samples).

* Hydraulic Studies Department to concurrently measure approach velocities across intake (profile).

** Hydraulic Studies Department to concurrently measure water trajectories leading to intake.

- c) to obtain baseline data for evaluation of sediment movement effects on fish spawning habitats.

2.0 STUDY AREA

Darlington NGS is located on the north shore of Lake Ontario about 64 km east of Toronto and 5 km west of Port Darlington. Pickering NGS is 32 km to the west of Darlington (Figure 1). The nearshore area off Darlington NGS is characterized by an exposed shoreline and a lake bottom that slopes approximately 8 m/km. A small embayment, McLaughlin Bay, is situated about 6 km west of Darlington NGS.

The condenser cooling water intake for Darlington is approximately 900 m offshore, at the 10 m depth contour (Figure 1). An underground discharge tunnel extends about 800 m offshore and connects to a 900 m long discharge diffuser. The diffuser is about 500 m (shortest perpendicular distance) west of the intake (Figure 1).

Most of the aquatic monitoring was conducted in the vicinity of the intake and the diffuser. Initially, control sites were chosen off Port Darlington and McLaughlin Bay, but these were relocated closer to Darlington NGS (3 km east and west) due to interference by gill nets with local boat traffic. The diffuser mixing zone is defined as an envelope of heated water that will be bounded by an isotherm 2 C° above ambient, and will have a total area of about 1 km². At the offshore end of the diffuser, the mixing zone radius will approximate 450 metres.

3.0 METHODS

3.1 Juvenile and Adult Fish Abundance

Sampling for juvenile and adult fish was conducted near the diffuser location within the mixing zone and along transects parallel to the diffuser at reference locations east and west of the station. Four surface and four bottom gill nets were set near the diffuser, while two surface and two bottom gill nets were fished at each reference location (Figure 1).

The two pairs of gill nets (surface and bottom) adjacent to the diffuser (locations B and C) were placed parallel to the diffuser, about 50 m on either side (Figure 1). The staggered arrangement was designed to position these nets at approximately the 10 m depth contour, which crosses the diffuser at several points along its length. The A and D pairs of gill nets were placed in line with the diffuser, at the inshore and offshore ends, and sampled the 8 m and 11 m depth contours, respectively, as well as the surface at these locations.

At the east and west reference locations, pairs of gill nets (surface and bottom) were set at the 8 m and 10 m depth contours to correspond with the depth range sampled near the diffuser. The east and west reference sites fished from May through October were located off Port Darlington and McLaughlin Bay, respectively. However, interference with local boat traffic resulted in alteration of the reference fishing locations in November and December (Memo: Carey to Maher 10/11/84). The reference fishing locations used in these months (and in subsequent years) were located 3 km east and west of Darlington NGS (Figure 1).

Each experimental gill net consisted of eight panels (each 5.2 m long x 1.5 m deep) with mesh sizes (stretched measure) ranging from 3.8 cm to 12.5 cm in 1.3 cm increments. Gill nets were set for one 24 hour period at each location. The proposed sampling frequency was once in December and twice in the months of May, July, October and November. However, as the fishing program was not finalized at the time of the May sampling, only bottom gill nets were fished at positions A-D (diffuser area) for a single 24 hour period during May.

Fish captured were identified to species and counted. Fork length, weight (where possible) and scale samples were obtained from salmonids and coregonids collected. Salmonid scales were sent to the Ontario Ministry of Natural Resources, while coregonid scales were retained for age and growth analysis. The state of maturity and sex ratios were determined (where possible) for salmonids and coregonids captured during the fall (October, November, December). Fish marks (finclips, tags) and external scars, injuries and external parasites were recorded from fall-spawning species. Wherever possible, live fish were returned to the lake.

Surface and bottom temperatures were recorded at all locations (inshore and offshore ends of nets) when gill nets were set and lifted.

3.2 Round Whitefish Fecundity

The fecundity of mature female round whitefish was determined by the gravimetric method. Ovaries from 25 females were preserved in Davidson's 'B' solution. The eggs were separated from the ovarian tissue, egg clumps were separated, and the eggs were air dried for three to five days. The entire egg mass from each fish was weighed (five significant digits accuracy). Then, a subsample of 200 eggs was counted and weighed on the same balance, within 10 to 15 minutes of the first weighing (to limit

weight change). Total fecundity (egg number) was computed from these data. To assess the variability inherent in the procedure, eggs from two fish were sampled in triplicate (three separate lots of 200 eggs were counted and weighed). Results (Appendix 2B) indicated ranges of 0.24% and 0.68% for the two sets of eggs. Thus, it may be assumed that error involved in the procedure is less than 1%. Total fecundities for the 25 fish sampled ranged from less than 3 000 to over 21 000 (Appendix 2B).

3.3 Mobile Sediment Monitoring

It was proposed to monitor small-scale bottom elevation changes (shifts in sand or fine sediments) in the nearshore zone off Darlington using depth-of-disturbance (DOD) rod measurements and photography of selected bottom areas by SCUBA divers.

Twelve observation points representing areas of either sand or cobble substrate were selected from images produced by side-scan sonar mapping. Observation points were located along several intersecting lines in the area of the diffuser and the intake (Figure 14). Each monitoring point was buoy-marked to facilitate re-occupation of the site (Appendix 3A). Loran-C coordinates were also obtained for each site.

The DOD measurements required calibrated steel rods (0.7 cm diameter) to be driven into the substrate to a fixed height above the bottom. A steel washer added to the rod would be allowed to settle to the bottom. On subsequent sampling occasions, divers would record the position of each washer to determine changes in bottom elevation. However, when divers inspected the substrate sites in September 1984, they found little (if any) soft substrates. On the hardpan clay substrates found at some sites, it was possible to drive rods only about 5 cm into the bottom. The rods would not penetrate the cobble or boulder beds found at most sites. Thus, it was concluded that DOD rod measurements were not suitable for use at Darlington unless substantial sand areas are found (or accumulate in the future). As an alternative to DOD measurements, visual estimates of the substrate composition were made by SCUBA divers at each substrate site when photographs were taken.

4.0 RESULTS AND DISCUSSION

4.1 Gill Net Fishing for Juvenile & Adult Fish

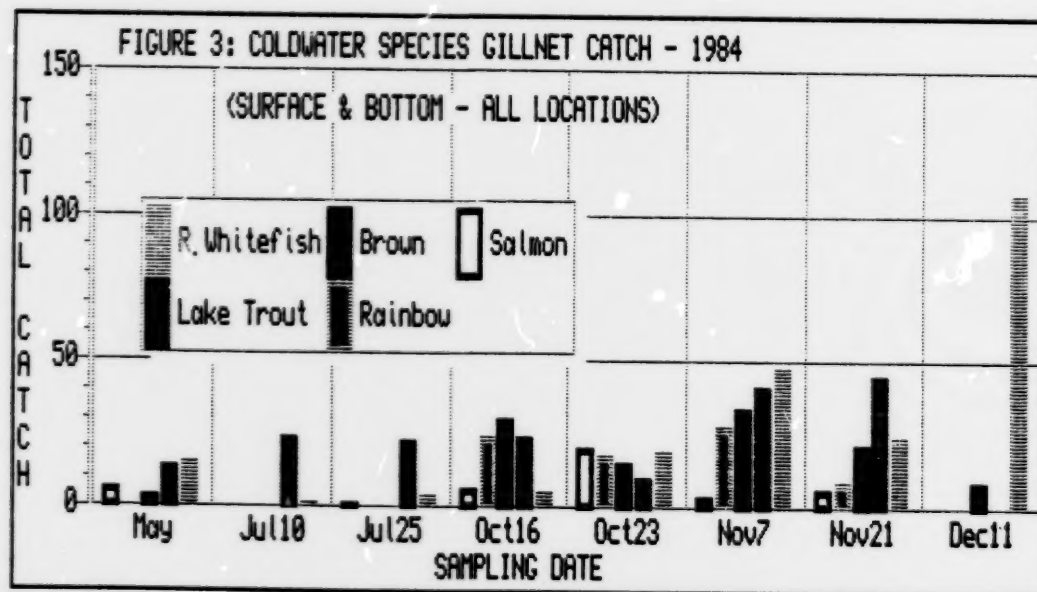
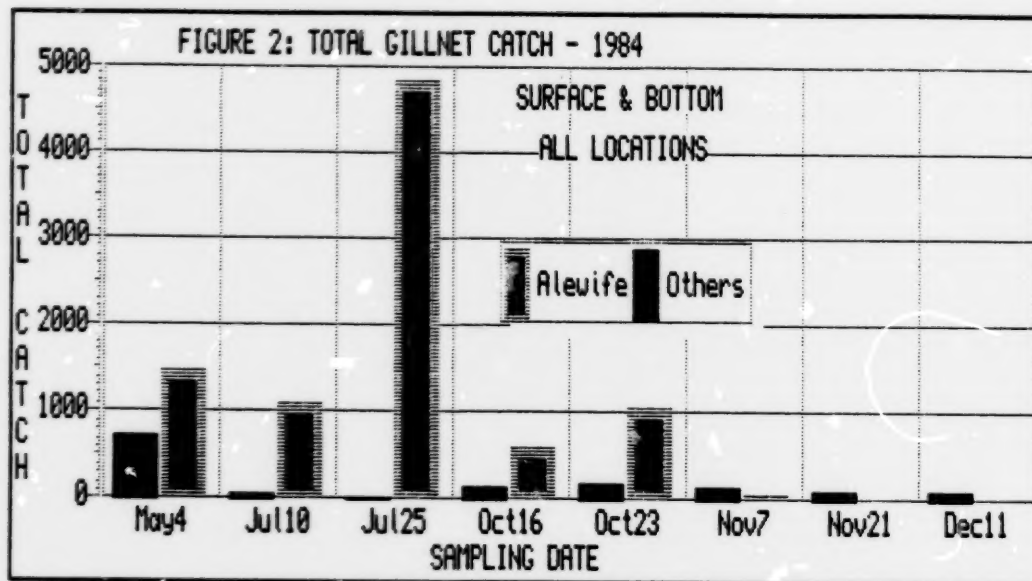
During the May to December period, 110 twenty-four hour gill net sets were completed, yielding a total catch of 11 180 fish (Appendix 1). Numerically, alewife dominated the catch, with

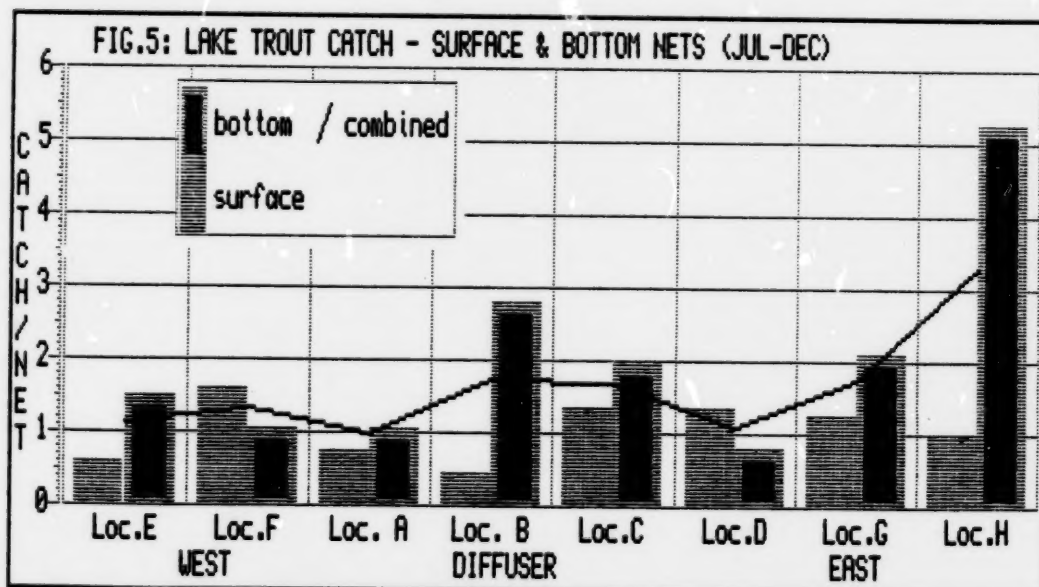
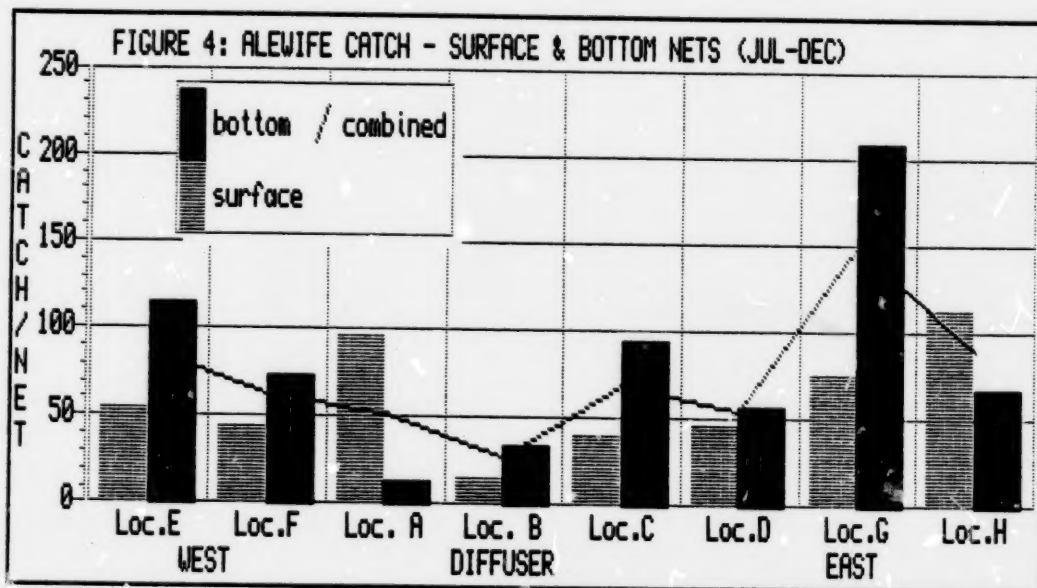
9 378 fish contributing 83.9% of the total catch. Rainbow smelt was the second most abundant species (853 fish = 7.6% of total catch). The third most common species was the round whitefish (237 fish = 2.12%). The lake trout was the most abundant salmonid species (190 fish = 1.70%), followed by brown trout (124 fish = 1.11%), rainbow trout (85 fish = 0.76%) and coho salmon (52 fish = 0.47%). A total of 130 common white suckers (1.16% of total catch) were also caught. They, like round whitefish, were collected almost exclusively in bottom-set nets, while most coho were taken from surface nets.

The seasonal distribution of alewife catch is illustrated in Figure 2. Although almost half the total alewife catch was taken during the July 25-26 sampling session, substantial numbers were present from early May until late October. It should be noted that catch values shown for May are the result of only four bottom nets, all fished near the diffuser (compared with 16 nets/session over the July to November period). Thus, the actual catch/unit effort (CUE) was 381 alewife in early May and 304 on July 25-26. During late fall and early winter, alewife numbers declined substantially. Ninety fish were taken on November 6-7 (5.6/net), 25 on November 20-21 (1.6/net), and none were caught during the December netting. Rainbow smelt contributed most to the catch of "other" species in May (717 caught) and were moderately abundant (74 fish) in the October 23-26 catch. Cold water species (round whitefish and salmonids) contributed most of the balance of the "other" species shown in Figure 2.

The seasonal catch distribution for cold water species is shown in Figure 3. Small numbers of round whitefish (17 fish) were taken in May and only a few were caught during July. Catches began to increase in late October, with the highest catch (109 fish) being taken in December. Lake trout were moderately abundant (10 to 25 fish/netting session) through the May to October period. Numbers peaked in November (43 - 46 fish) and none were caught in December. Brown trout were moderately abundant (10 to 35 fish/session) throughout the fall and early winter period (October to December). Pacific salmon (almost entirely coho) were taken in substantial numbers (22 fish) only in late October.

The spatial distributions of catch for the most common species are next considered. Average alewife catch/net (CUE) for the July to December period is shown in Figure 4. May catches are not included, as only the diffuser sites were fished at that time. As the reference fishing areas were changed after the October netting (see Methods), values shown for the reference locations (E, F, G and H) are composites based on sampling



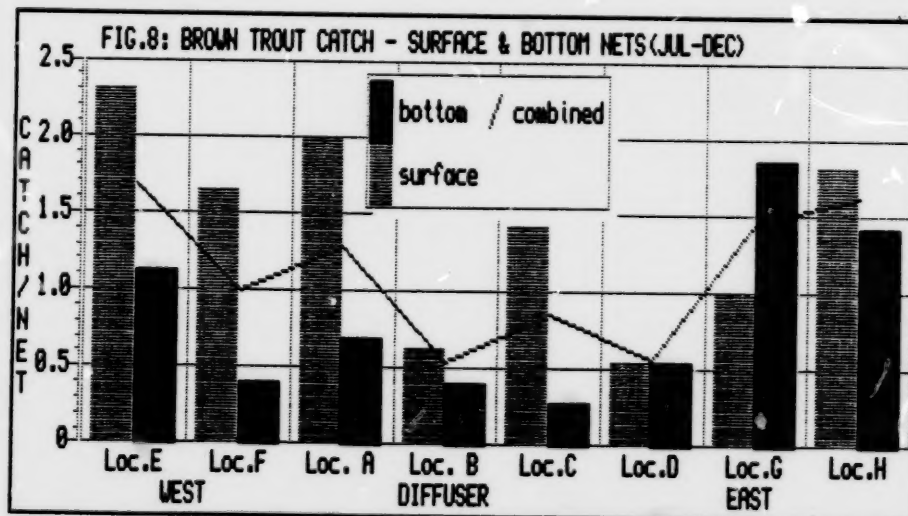
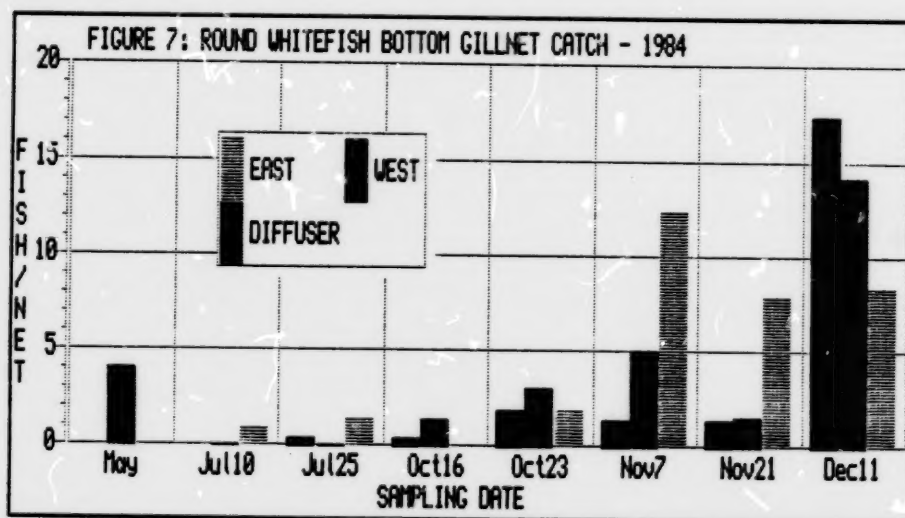
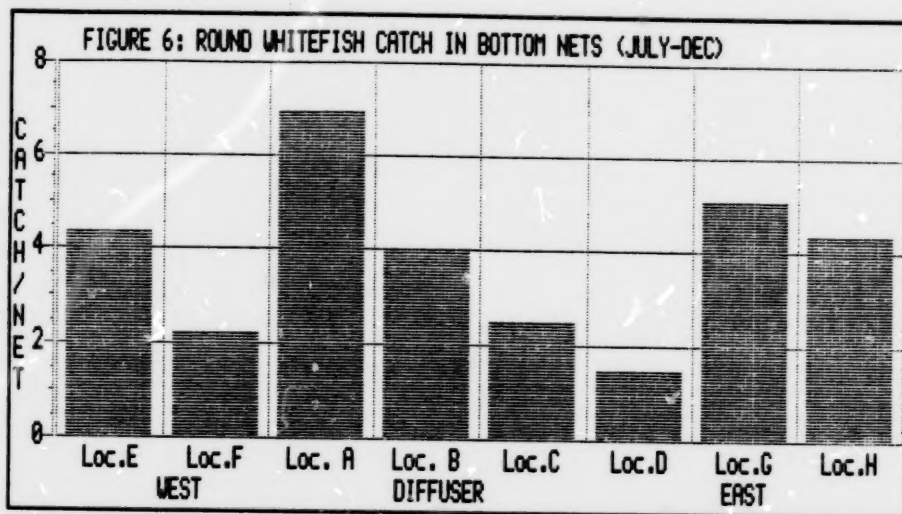


different sites. Results indicate a higher average catch in bottom nets (4750 alewife total) compared with surface nets (3 105 alewife). Variability in catch between sites and in the relative contributions of surface and bottom nets was very high. However, it appears that average combined (surface and bottom) catches in the diffuser area (locations A to D; 27 to 69 fish/net) were somewhat lower than those in the reference areas, especially the east reference area, where the average catch ranged from 90 to 149 alewife/net. Combined (surface + bottom) results also suggest higher catches inshore at both reference sites, but this was not the case at the diffuser, where higher average catches were obtained at the offshore sites (C and D).

Lake trout catches were generally higher in bottom nets (2.12 fish/net) than in surface nets (1.11 fish/net) averaged over all sites (Figure 5). Combined bottom + surface catches were comparable for the diffuser and the west reference area (1.0 to 1.77 fish/net) but higher (1.77 to 3.30 fish/net) at the east reference area. The largest individual catch (16 lake trout) was obtained from a bottom net at the offshore east reference site (Location H). While catches at the reference sites were somewhat higher offshore, there was no clear pattern evident at the diffuser (sites A to D).

Round whitefish were collected only in bottom nets (Figure 6). Over the July to December period, average catches were similar for the reference locations (4.07 fish/net) and the diffuser locations (3.79 fish/net). Results indicate a higher average catch for inshore sites than for offshore sites (compare E versus F, A to D, G versus H). Although the seasonal average catches were similar for the diffuser and the reference areas, it should be noted that the largest single catch (36 fish) was taken at the inshore end of the diffuser (Location A) on December 11. The seasonal pattern of catch in Figure 7 indicates that during the early phases of the onshore migration in November, catches were highest at the east reference area, whereas higher average catches were obtained at the west reference area and the diffuser in December.

Brown trout catch results are shown in Figure 8. Averaged over all locations, more brown trout were taken in surface nets (71 fish = 1.44/net) than in bottom nets (44 fish = 0.86/net). No clear pattern of spatial distribution was evident. Offshore average catches were slightly lower than inshore catches at the west reference area and the diffuser, but the reverse was true at the east reference area. Over the July to December period, the average catch for the diffuser locations (0.82 fish/net) was somewhat lower than that for the reference areas (1.44/net).



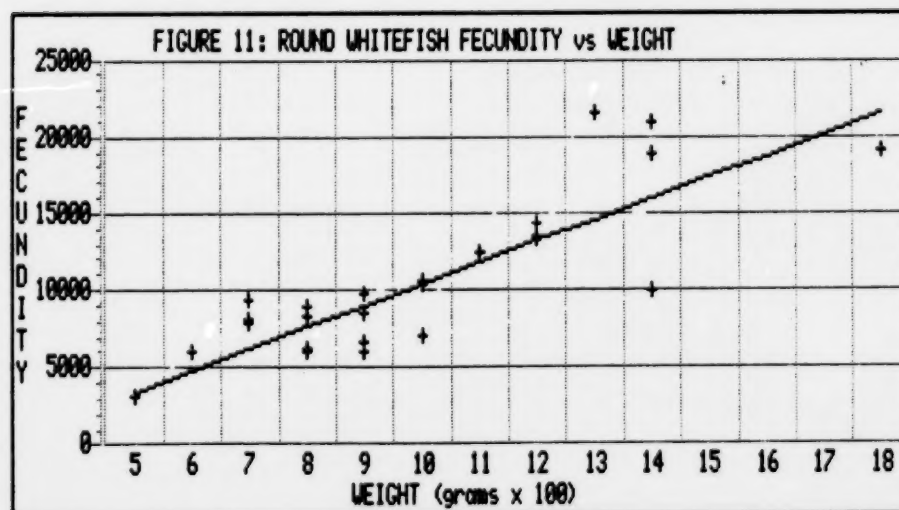
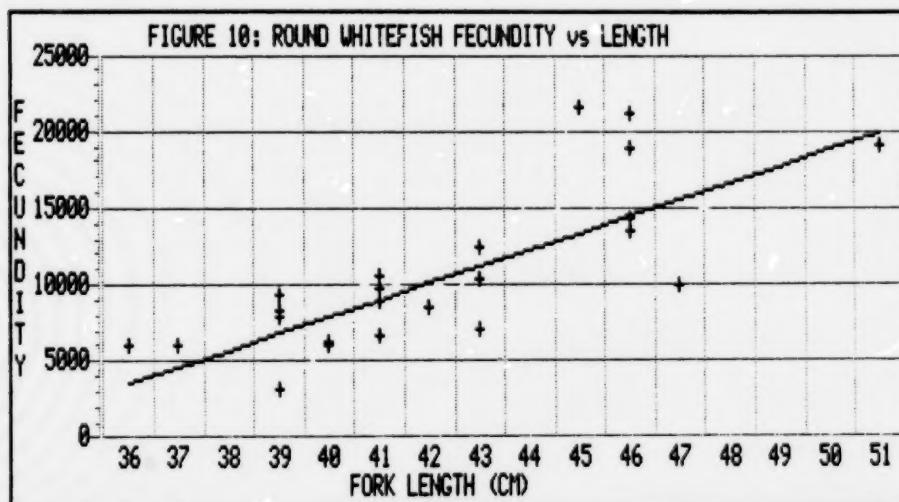
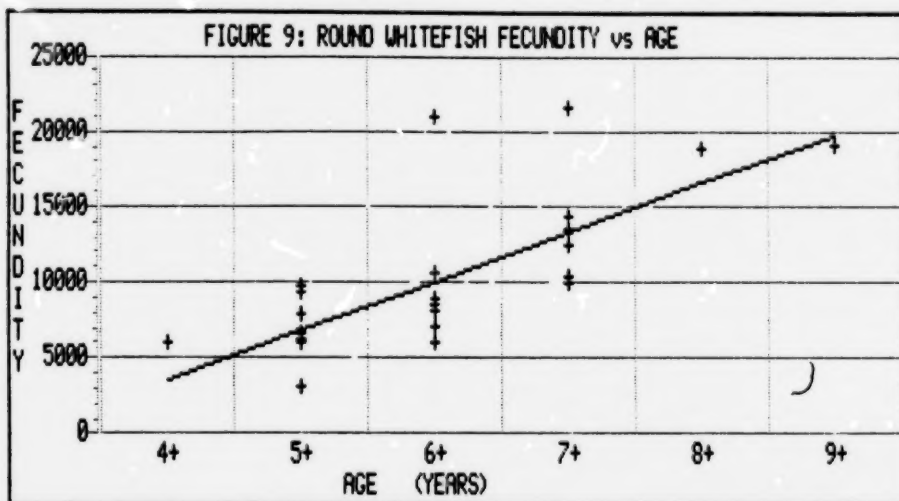
4.2 Fecundity and Meristics of Round Whitefish

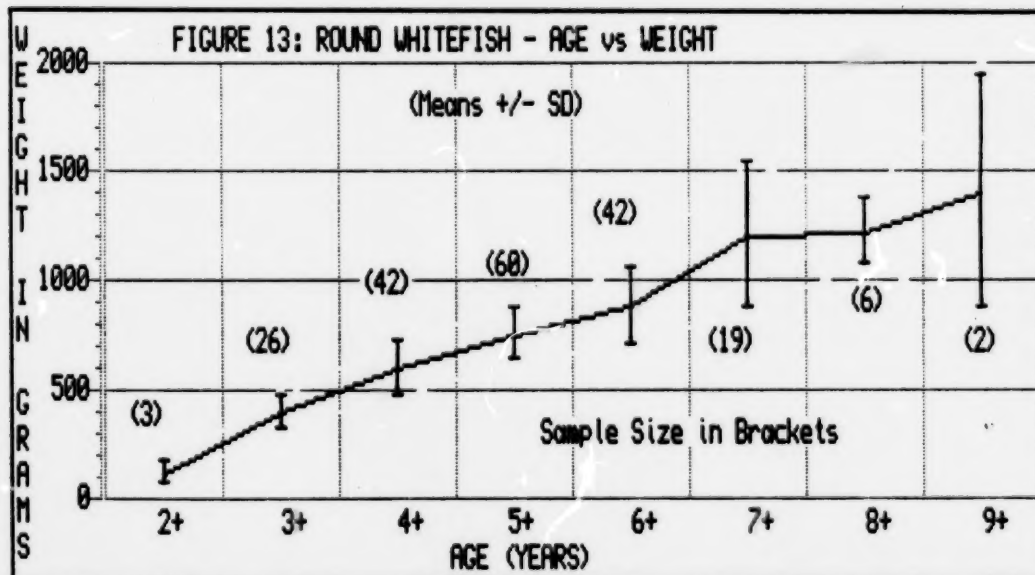
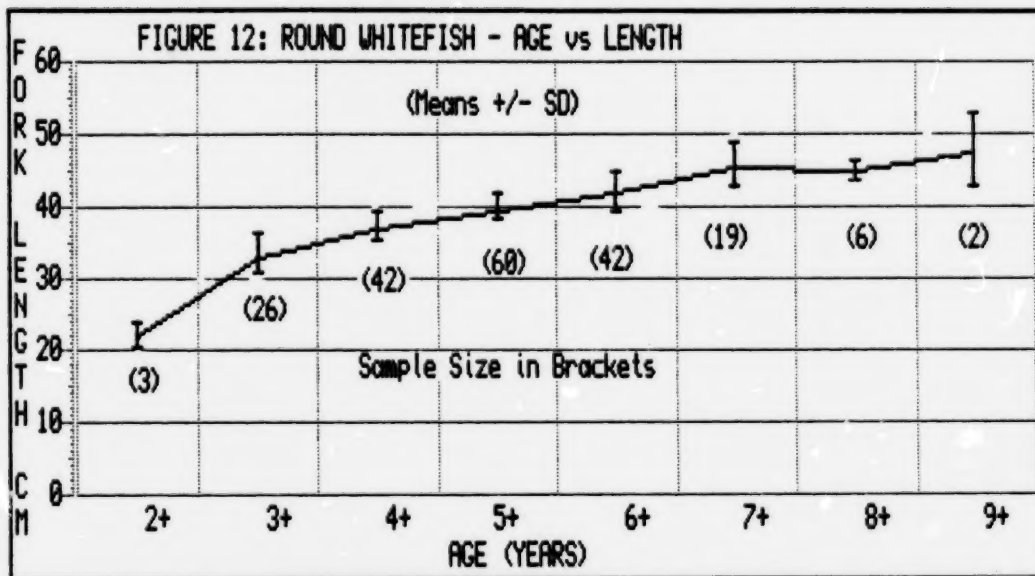
Data on fecundity, length, weight and age from 25 female round whitefish collected for fecundity estimates on December 11, 1984 are listed in Appendix 2B. Meristic data (length, weight, age) from 200 round whitefish collected throughout the netting season are listed in Appendix 2A. Linear regressions were computed relating fecundity to fork length, weight and age (Appendix 2C). Correlation coefficients for these regressions ranged from 0.73 (fecundity versus age) to 0.84 (fecundity versus weight). Similar regressions fitted to log-transformed data are also included in the appendix. However, as correlation coefficients were not generally improved by log transformation, only the untransformed results have been plotted. The fecundity versus age relationship is shown in Figure 9. In this figure, the regression line is shown, along with the individual data values ('+' symbols). This regression yielded the poorest fit ($r = 0.73$) and the plot suggests that improvement might be gained through future sampling of both older (age 8+, 9+) and younger (age 3+, 4+) fish. In general, the regression indicates a fecundity of 3 600 eggs/female for fish aged 4+, increasing by 3 200 eggs for each additional year attained (to 19 800 for a fish aged 9+).

The youngest fish included in the present fecundity estimates was aged 4+. Extrapolation of the regression in Figure 9 suggests minimal fecundity (419 eggs/female) for age 3+, and no fecundity (negative value) for age 2+. In contrast, sampling by Haymes and Kolenosky (1984), which covered the Lake Ontario north shore from Pickering to Wesleyville over the 1976 to 1981 period, indicated that 17% of age 2+ females and 90% of age 3+ females were mature. Thus, it is suggested that additional samples of young fish (age 2+ to 4+) will be required to better define fecundity relationships for these ages.

The fecundity versus length and fecundity versus weight relationships are shown in Figures 10 and 11, respectively. Somewhat better correlations ($r = 0.77$ for length and $r = 0.84$ for weight) were obtained in these regressions. However, the plots again indicate the need to further sample both small and large individuals.

Age versus length data and age versus weight data for 200 round whitefish collected from Darlington in 1984 are shown in Figures 12 and 13, respectively. Growth results are similar to those reported by Haymes and Kolenosky (1984) for the Lake Ontario north shore as a whole. In the aging procedure used here, scale radii were measured for the scale margin and each annulus attained. Thus, the results may be used to fit a scale





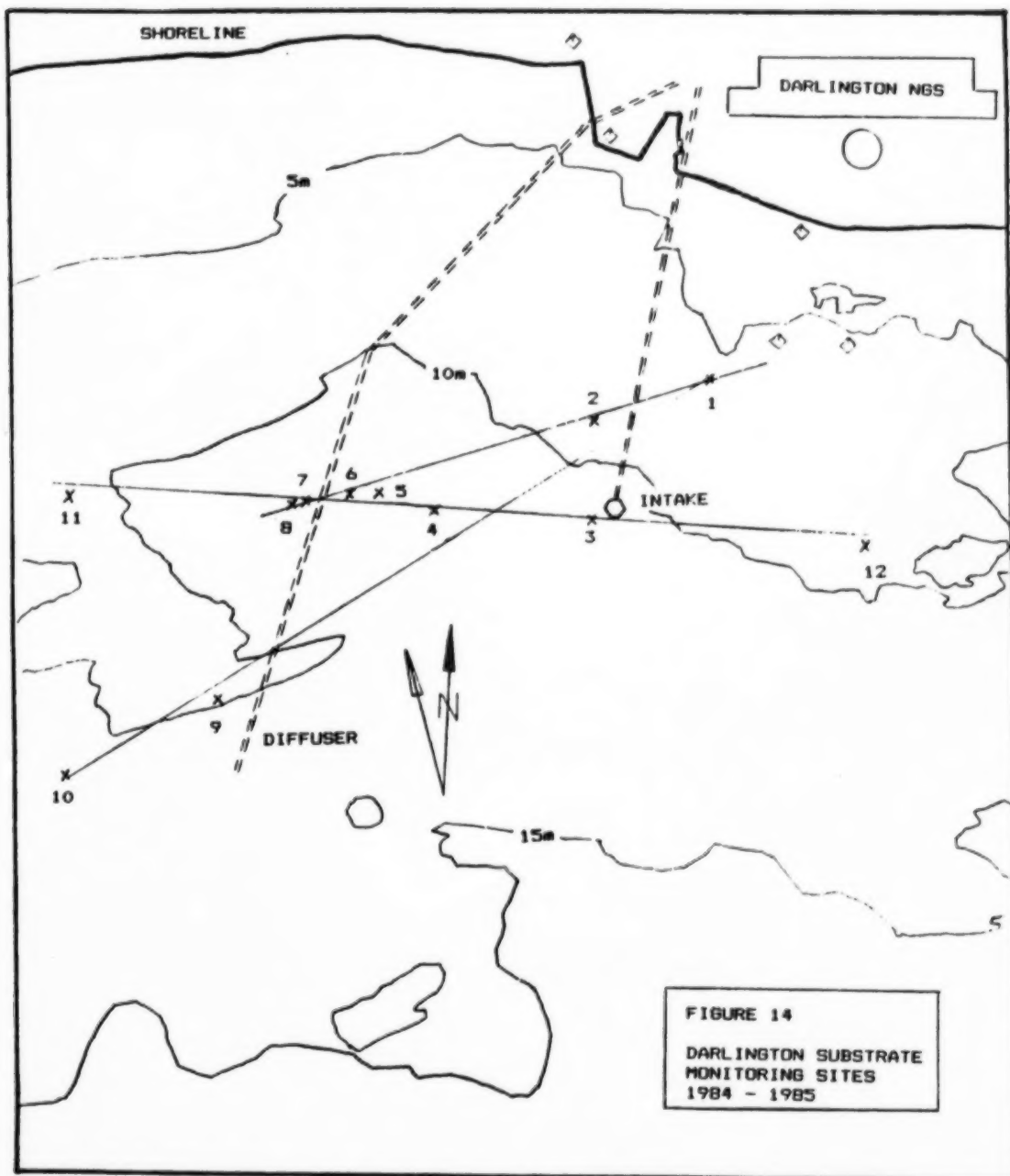
versus body length regression, and then back-calculate size at all previous ages for each fish (OHRD Report No 78-52-K). Sufficient data should be available to conduct this analysis after the 1985 sampling year. Growth relationships will then be up-dated on an annual basis thereafter.

The mean age of round whitefish collected at Darlington in 1984 was 5+ years, compared with mean ages of 5+ for 1977 gill net samples and 4+ for 1980 samples (Haymes and Kolenosky, 1984). It should be noted that the mean age of the 25 fish used for fecundity estimates was 6+ years. Thus, an average fecundity value based on this age was 10 116 eggs/female (Figure 9). However, if the true mean age of the spawning population is 5+ years, then an average fecundity of 6 884 eggs/female results. Given that the majority of whitefish sampled were taken during the fall spawning period (in the present study, in 1980 and 1977), then the value for age 5+ fish is likely the present best estimate for average fecundity of the Darlington round whitefish population.

4.3 Mobile Sediment Monitoring

In order to provide baseline information to assess effects of possible bedload (sediment) shift on round whitefish spawning success, 10 substrate sites were selected (on the basis of side-scan sonar traces) for periodic inspection. The sites were located along three intersecting lines, one extending offshore from the vacuum building to the southwest corner of the diffuser mixing zone, the second from the area of the intake to the diffuser, roughly parallel to shore, and the third running from the diffuser to the area directly offshore from the vacuum building (Figure 14). All locations appeared to have a cobble substrate suitable for spawning. Sites S1 and S4 were located on ridges. Site S3 appeared to be covered by rippled sand. Sites S5 to S8 were expected to have maximum exposure to the diffuser current, while Sites S9 and S10 should have maximum exposure to plume temperatures. Two additional sites were added in the late fall of 1984. These sites (Figure 14) were located along the shore-parallel line, about 0.5 km east of the intake (S12) and 0.5 km west of the diffuser (S11). It is believed that these locations will not be affected by currents created by the intake and diffuser.

As previously described in the Methods section, depth of disturbance (DOD) rod measurements originally proposed were not feasible due to the hard substrates encountered at most sites. Observations were continued visually, supplemented by photography of the substrate when conditions permitted. The initial 10 substrate sites were inspected on October 4, 1984 and all 12



sites were inspected on November 30, 1984. Inspections scheduled for the early spring of 1985 were not done due to adverse weather and boat availability problems. Inspection of the sites was completed on September 11, 1985 and these latter results are included in the present report. A description of the information gathered to date for each site follows. Detailed data are listed in Appendix 3.

Substrates observed were characterized by particle size as follows:

1. Boulder: > 254 mm
2. Cobble: 64 - 254 mm
3. Pebble: 8 - 64 mm
4. Gravel: 2 - 8 mm
5. Sand: 0.063 - 2 mm
6. Clay: 0.001 - 0.063 mm

These particle sizes are used for classification of substrates by screening. In the present study, substrate composition was estimated visually (by divers and from substrate photos), using these particle size ranges as a guide. While visual estimates are subjective and may vary among divers (especially with regard to classification of materials in adjacent size classes), the extreme spatial heterogeneity of these substrates makes detailed measurement of small samples (grab samples, substrate photos) impractical. Thus, despite the shortcomings of visual diver estimates, the method used does allow a reasonable overview of substrate composition at the selected sites. The following site descriptions were based on both the diver's notes and the available photographs.

Site #1

This location, at a depth of 6.5 m, is characterized by boulders (25 to 60%) and cobble (40 to 60%) material (Figure 15). A small amount of sand (10%) was noted on October 4/84 and clay (15%) was reported on September 11/85.

Site #2

This 8 m deep site (Figure 15) is dominated by boulders (40 to 80%), with a moderate amount of sand (20 to 25%). Some cobble and clay were noted in 1984 observations, but not in 1985.

Site #3

This 10 m deep site, located at the southwest corner of the intake (Figure 16), represents the largest concentration of sand (70 to 75%) observed at any substrate location. Small amounts

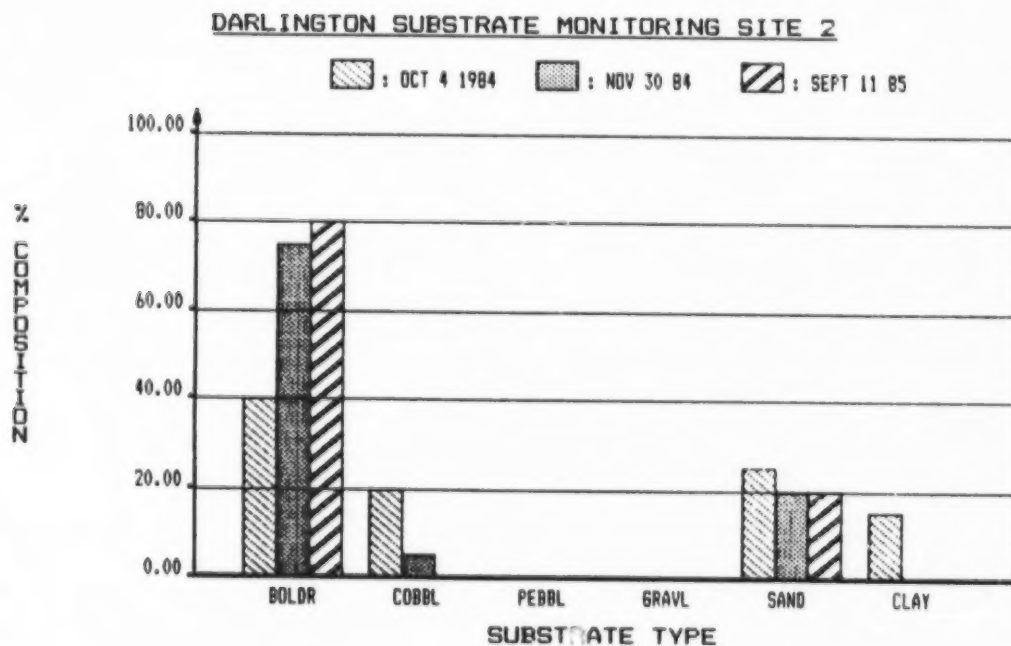
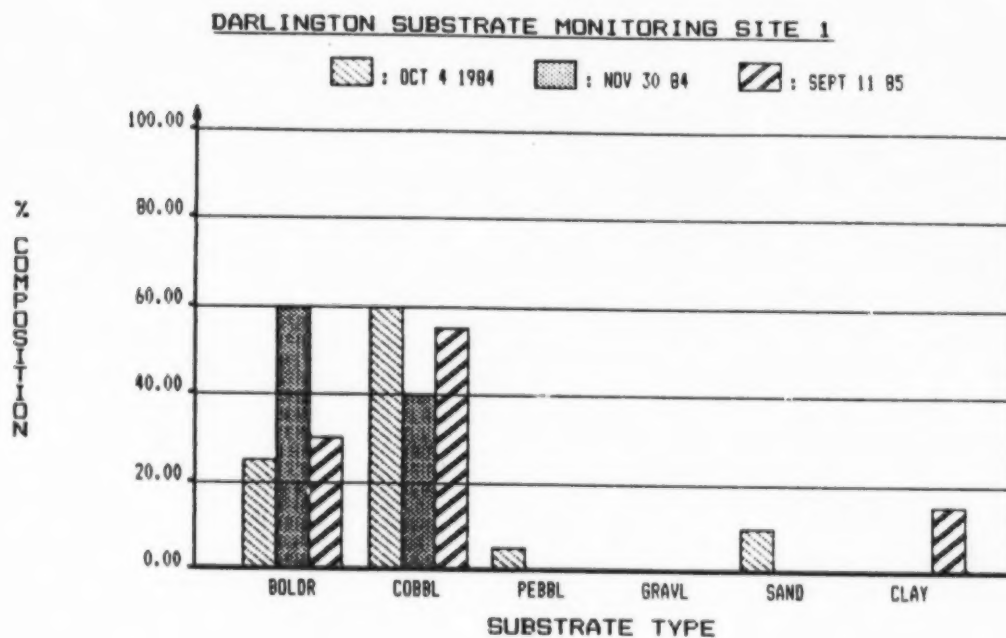
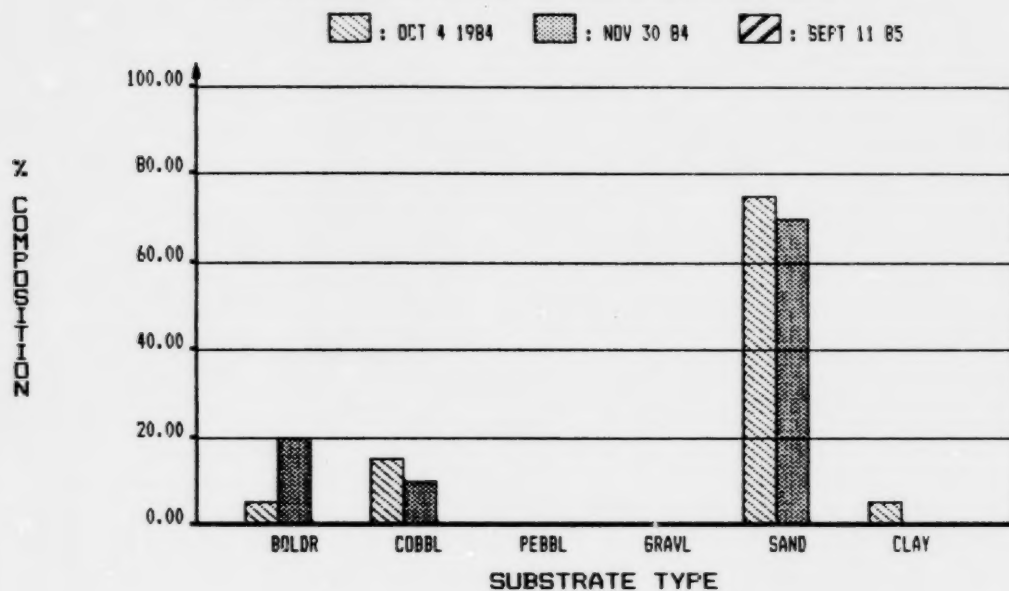


FIGURE 15

**DARLINGTON SUBSTRATE MONITORING
SITES S1 & S2: 1984 - 1985**

DARLINGTON SUBSTRATE MONITORING SITE 3



DARLINGTON SUBSTRATE MONITORING SITE 4

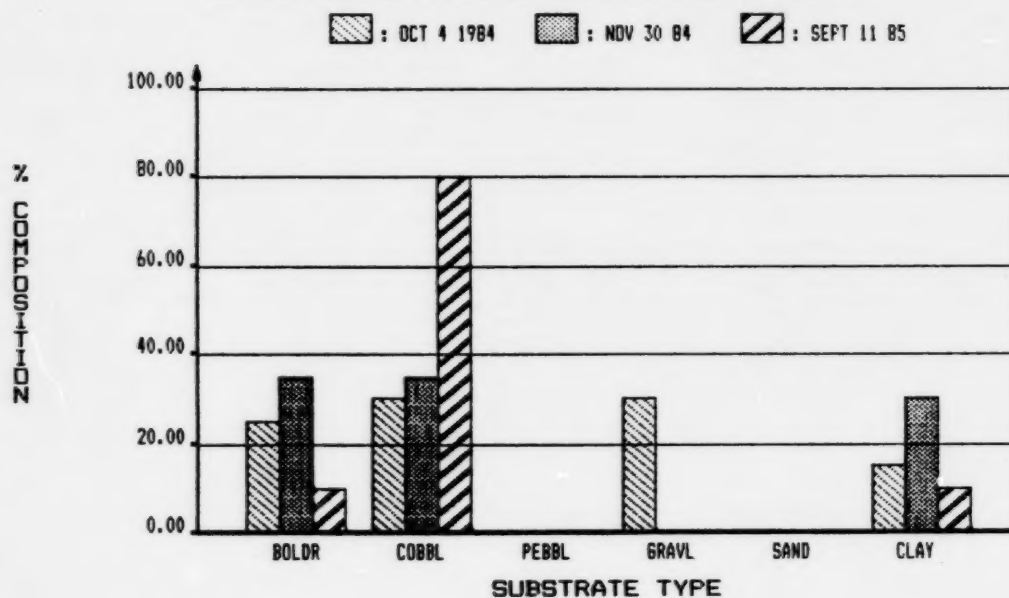


FIGURE 16

**DARLINGTON SUBSTRATE MONITORING
SITES S3 & S4: 1984 - 1985**

of boulder and cobble were noted during both inspections in 1984. It was not possible to monitor this site in September 1985, as the location was occupied by equipment involved with intake construction.

Site #4

This 10.5 m deep site (Figure 16) is located on a ridge (approximately midway between the intake and the diffuser line) composed largely of boulders (10 to 35%) and cobble (30 to 80%). About 30% gravel was observed on October 4/84, but not on subsequent inspection dates. Clay (10 to 30%) was observed during all three inspections.

Site #5

This site, at 11.5 m depth, is located about 100 m east of the diffuser line. The substrate (Figure 17) is largely cobble (30 to 60%), boulder (15 to 25%) and gravel (10 to 50%). Considerable variability exists in the proportions of these constituents reported on the three inspection dates. Also, bedrock (30%) and sand (5%) were noted on September 11/85, but not during the 1984 observations.

Site #6

This 11 m deep site is located about 50 m east of the diffuser line. The substrate (Figure 17) is mostly boulder (40 to 60%) and cobble (30%). Small amounts of gravel, sand, clay and bedrock (10 to 20%) have been observed, although these minor constituents were not reported on all monitoring dates.

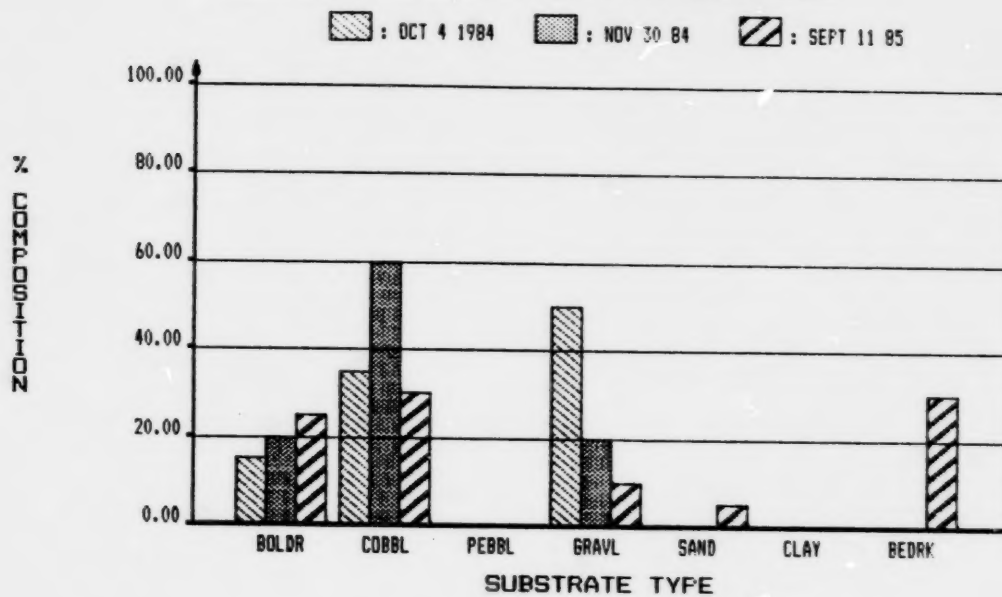
Site #7

This 11.5 m deep site is located 50 m west of the diffuser line. The substrate (Figure 18) is largely boulder (40 to 60%) and cobble (30 to 40%). Clay (15 to 20%) was noted in the 1984 sampling. Sand (5%), gravel (10%) and bedrock (10%) were reported on single sampling occasions. Some disturbance of the substrate (from diffuser construction) was evident at this site.

Site #8

This site, at 11 m depth, is located about 100 m west of the diffuser line. The substrate (Figure 18) is mostly cobble (30 to 70%), with some boulder (10 to 40%) and gravel (20 to 30%). Small amounts of sand (2 to 5%) and clay (8 to 15%) were observed in the fall of 1984.

DARLINGTON SUBSTRATE MONITORING SITE 5



DARLINGTON SUBSTRATE MONITORING SITE 6

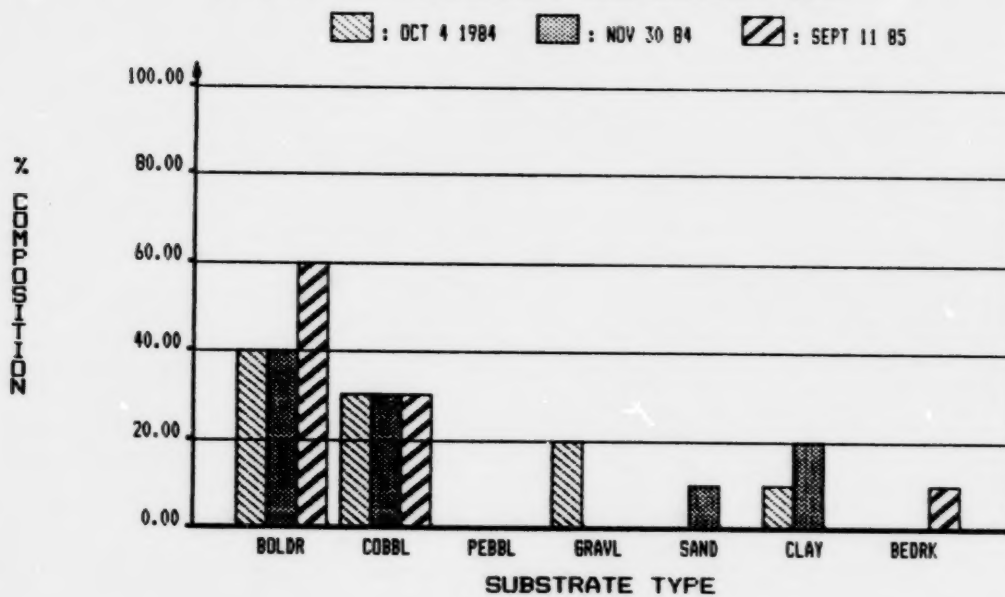


FIGURE 17

**DARLINGTON SUBSTRATE MONITORING
SITES S5 & S6: 1984 - 1985**

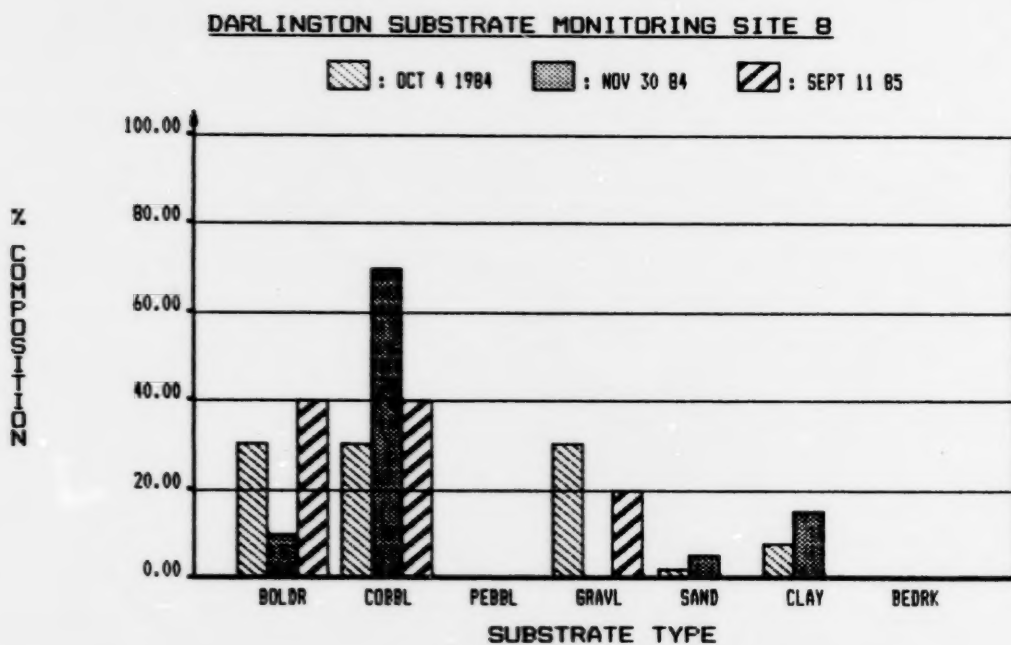
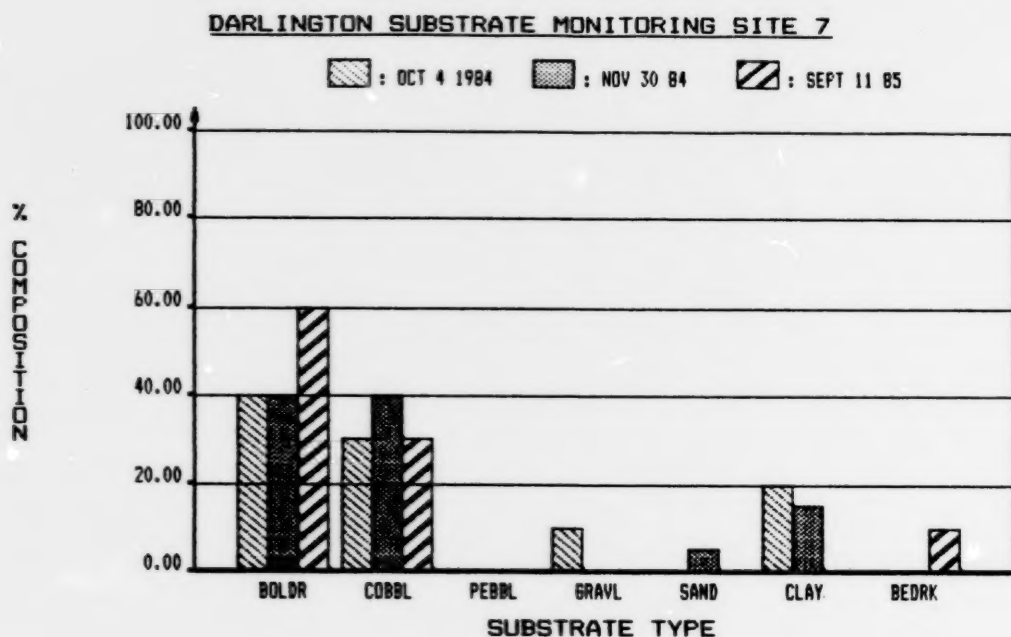


FIGURE 18

**DARLINGTON SUBSTRATE MONITORING
SITES S7 & S8: 1984 - 1985**

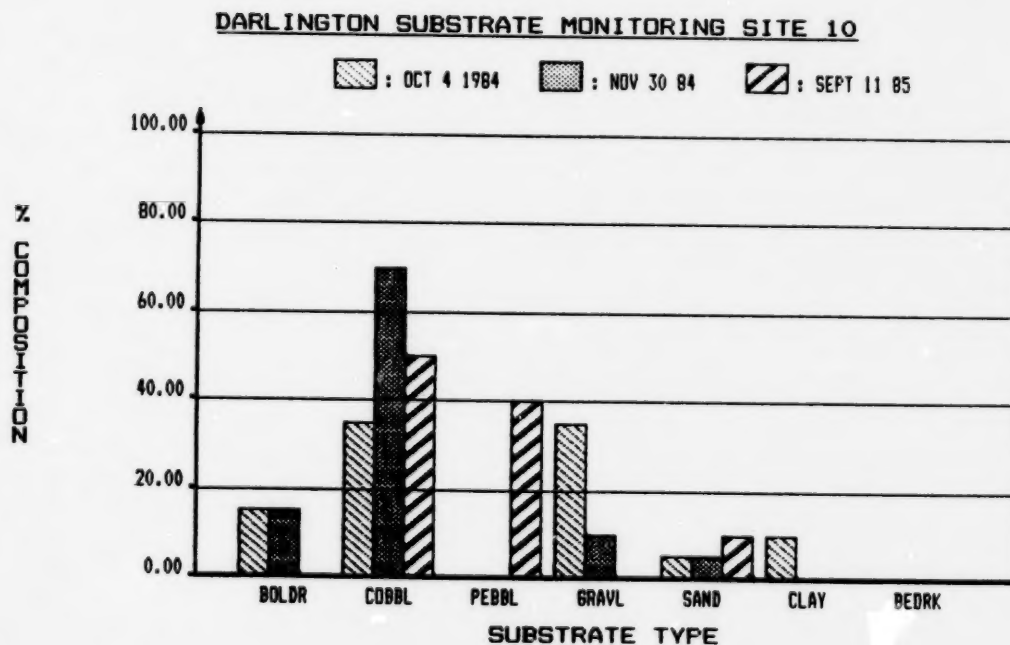
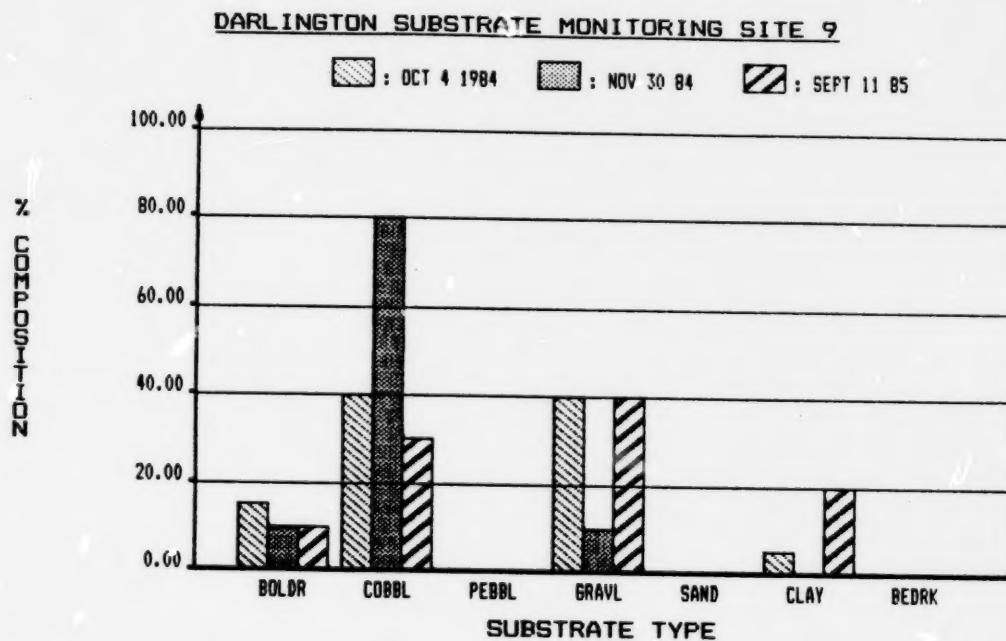


FIGURE 19

**DARLINGTON SUBSTRATE MONITORING
SITES S9 & S10: 1984 - 1985**

Site #9

This 10 m deep site is located about 100 m west of the diffuser line, about 150 m from the offshore end. The substrate (Figure 19) is largely cobble (30 to 80%), gravel (10 to 40%) and boulder (10 to 15%). Some clay (5 to 20%) was also observed.

Site #10

This site at 11.5 m depth is located near the southwest corner of the discharge mixing zone, approximately 350 m west of the offshore end of the diffuser line. The substrate (Figure 19) is mostly cobble (35 to 70%), pebble (40%) and gravel (10 to 35%), with some boulders (15%). Sand (5 to 10%) was observed during all three inspections. Clay (10%) was observed only on October 4/84.

Site #11

This 10 m deep site is located approximately 500 m west of the diffuser line. The substrate (Figure 20) is mostly boulder (40 to 50%) and cobble (40 to 50%). Some sand (10%) and clay (10%) were noted during the November 30/84 inspection.

Site #12

This site, at 9 m depth, is located approximately 500 m east of the CCW intake. The substrate (Figure 20) is almost entirely cobble (80 to 90%), with some boulders (10 to 20%). No fine materials (gravel, sand, clay) were observed at this site.

This study resulted from the concern that incubating eggs (primarily round whitefish) may be adversely affected by movement of fine sediments (sand, silt), especially if deposition patterns are altered by Darlington NGS intake and diffuser currents. If eggs are covered by fine sediments, their respiration will be impaired and high mortality will likely result. The inspections completed to date show little evidence of fine silt at any site. The clay materials observed are largely in the form of compacted ridges, exposed areas of hardpan, or material embedded in boulder/cobble fields. Movement of this material seems unlikely. Thus, the main cause for concern is the movement of sand particles. Sand has been observed (in at least one inspection period) at 9 of the 12 monitoring locations. Sand was observed during all inspections at three sites: S2 (20 to 25% coverage), S3 (70 to 75%) and S10 (5 to 10%). Observations during the 1985 field year indicate substantial areas of sand accumulation in the vicinity of the St. Mary's Cement Co. dock,

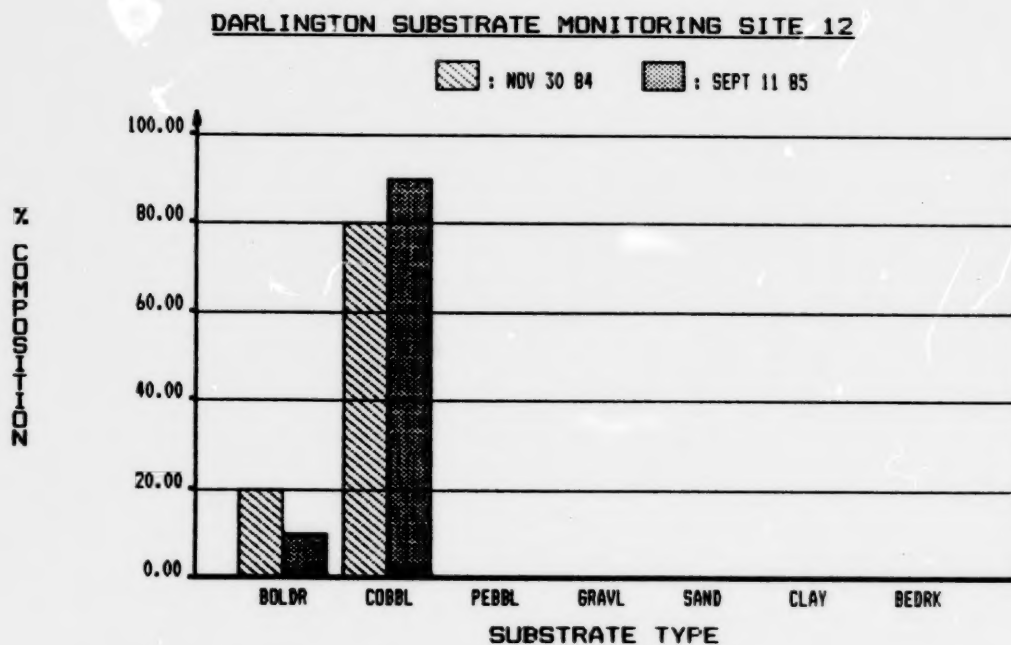
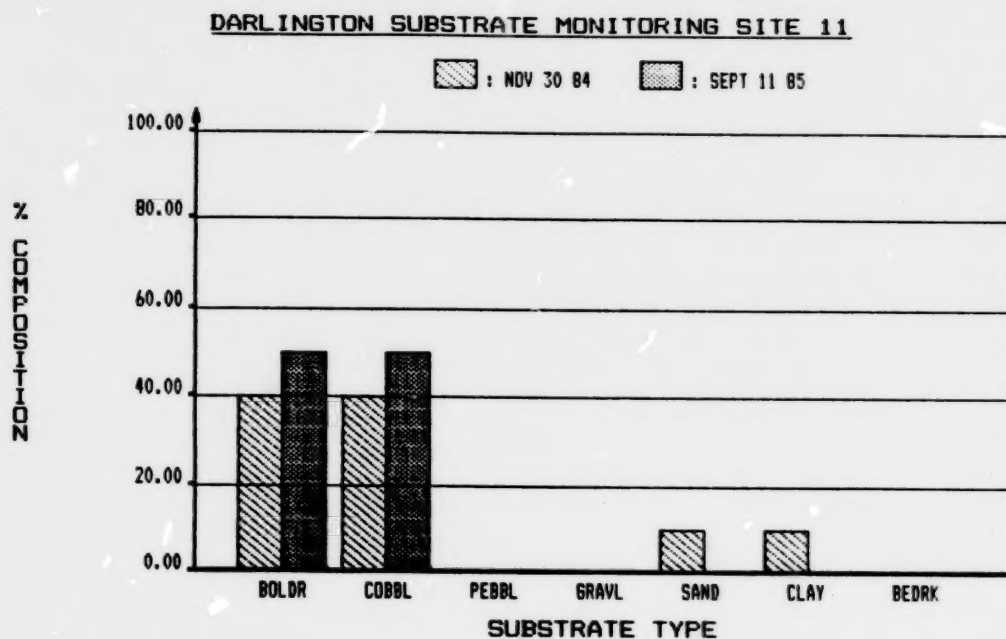


FIGURE 20

**DARLINGTON SUBSTRATE MONITORING
SITES S11 & S12: 1984 - 1985**

to the east of Darlington NGS. Also, accumulation of sand in the Darlington NGS dock area and the CCW intake excavation indicates that sand in the area is quite mobile. Thus, large-scale movement of sand into the study area (from the accumulation at St. Mary's) is possible during storms.

Although observations made at the 12 substrate monitoring sites in 1984 and 1985 suggest differences in the presence (or amount) of sand at several sites over this period, these results may not be indicative of sand movement. As repeated observations were not made in precisely the same spot on each occasion, results largely reflect the heterogeneity of the substrate. This is readily apparent when one considers the variation in estimates for larger, non-mobile substrate components (compare estimates for boulder and cobble at each site in Figures 15 to 20). The use of several divers probably also contributed to this variability, especially in the classification of materials in adjacent size classes (boulder/cobble, gravel/sand, sand/clay). The problem of reproducibility of results was further compounded by removal of the spars marking substrate sites in the spring of 1985 to minimize interference with boat/barge traffic associated with construction of the CCW intake. Sites were located in September/85 on the basis of Loran-C coordinates (Appendix 3A). Thus, some sites inspected on September 11/85 may have been up to 50 m distant from those inspected in the fall of 1984.

Substrate monitoring procedures were modified for the 1986 field year to improve the reproducibility of results. Use of a permanent reference marker at each site plus new procedures for photography and visual substrate composition estimates should improve the quality of future data. Also, the possibility of using video equipment (mounted in a remotely controlled submersible) may be explored in 1987. This equipment would provide a permanent videotape record of substrates for ongoing comparisons.

Substrate inspections will be made on a regular basis (quarterly suggested) throughout the preoperational phase. More frequent inspection may be warranted once Darlington becomes operational or if the data indicate substantial movements of sand.

5.0 SUMMARY

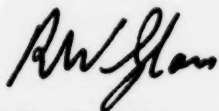
1. Juvenile and adult fish were sampled in 110 gill net sets over the May to December period, yielding a total catch of 11 180 fish. Alewife numerically dominated the catch (83.9%), followed by rainbow smelt (7.6%). Cold water species (round whitefish, salmonids) accounted for 6.2% of the catch (688 fish). Of these species, round whitefish was

the most abundant (237), followed by lake trout (190), brown trout (124), rainbow trout (85) and coho salmon (52).

2. Alewife abundance was highest in the May to July period and declined sharply after October. None were caught in December. Smelt were most abundant in May. Round whitefish numbers increased during the fall and peaked in December (the spawning period). Lake trout were moderately abundant in May, July and October. Numbers peaked in November. Peak catches of brown trout and rainbow trout also occurred in November, while coho salmon were abundant only in October.
3. Average alewife catches were lower in the diffuser area than in the reference areas, although the data were highly variable. Both lake trout and alewife catches were highest (yearly average) at the east reference site, but there was no correlation in the catches of these two species, as peak abundances occurred at different times of the year. Round whitefish were collected only in bottom nets, and average catches were similar for the diffuser and reference areas. However, the largest single catch (36 round whitefish) occurred at the inshore end of the diffuser in December. No clear pattern of spatial distribution was evident for brown trout.
4. Regressions relating age, length and weight to round whitefish fecundity were determined from 25 females sampled in December. Fecundities ranged from 3 600 eggs/female for fish aged 4+ to 19 800 eggs/female for fish aged 9+. Overall catch data suggest an average age for the population of 5+, yielding a fecundity of approximately 6 900 eggs/female. Growth data obtained from 1984 samples (200 fish aged) appear similar to results reported for populations along the north shore of Lake Ontario by Haymes and Kolenosky (1984).
5. Twelve substrate monitoring sites (from 6.5 m to 11.5 m depth) were selected to provide baseline information on movement of sediments which may adversely affect incubating fish eggs. Sites were inspected in October and November/84. An additional inspection scheduled for the spring of 1985 was not completed until September/85. Sand appeared to be the substrate material most likely to be shifted by lake currents or storms. Some sand was observed at nine sites, but consistently only at three sites. Procedural problems were recognized which may have contributed to the apparent movement of sand at some sites. Procedures have been

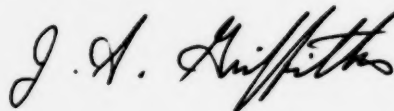
modified to improve reproducibility of future results. Observations made in 1985 suggest that sand in the area is quite mobile. Substantial areas of sand were observed near the St. Mary's Cement dock to the east of Darlington. Thus, large-scale sand movement into the study area (from St. Mary's) appears possible during storms.

Approved by:



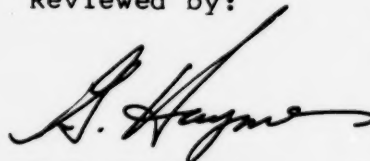
for M.R. Booth
Acting Manager
Chemical Research Dept

Prepared by:



J.S. Griffiths
Biologist
Biological Research Section

Reviewed by:



G.T. Haymes
Acting Supervising Biologist
Biological Research Section

JSG:lg

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- Greig, L.A., G. Cunningham, R.R. Everitt and M.L. Jones. 1984. Final report of two workshops to consider the environmental effects and monitoring options for the Darlington NGS. Report to Ontario Hydro, ESSA Environmental and Social Systems Analysts Ltd. April, 1984.
- Haymes, G.T. and D.P. Kolenosky. 1984. Distribution and characteristics of spawning round whitefish in Lake Ontario, 1976-1981. Ontario Fisheries Technical Report Series No 14.
- Ontario Hydro Design & Development Division Report No 84252. Outline of environmental pre-operational and post-operational studies for Darlington GS. J.F.B. Maher, July, 1984.
- Ontario Hydro Research Division Report No 78-52-K. Fish growth at Great Lakes generating station sites. J.S. Griffiths, February, 1978.

APPENDIX 1 A
DARLINGTON GILLNET CATCH - MAY 4, 1984

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Catch/net
alewife	482	212	383	446					1523	380.75
seelt	27	142	221	327					717	179.25
round whitefish	10	3	1	3					17	4.25
lake whitefish									0	0
lake trout	2	4	8	1					15	3.75
brown trout		3		2					5	1.25
rainbow trout									0	0
coho salmon	2	5		1					8	2.00
chinook salmon									0	0
white sucker	1		2						3	.75
redhorse sucker									0	0
freshwater drow									0	0
brown bullhead									0	0
lake chub									0	0
yellow perch									0	0
white perch									0	0
white bass									0	0
gizzard shad									0	0
smallmouth bass									0	0
longnose sucker	4			4					8	2.00
Site Totals	528	369	615	784	0	0	0	0	2296	574.00
									Session Total	

* = sites not fished

APPENDIX 1 B

DARLINGTON GILLNET CATCH - JULY 10, 1984
(BOTTOM NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife	2	39	63	32	29	1	6	10	182	22.75
smelt	4	3	2	1			1		11	1.375
round whitefish			1				1	1	3	0.375
lake whitefish									0	0
lake trout	2	1			1	1	1	3	9	1.125
brown trout									0	0
rainbow trout									0	0
coho salmon									0	0
chinook salmon									0	0
white sucker									0	0
redhorse sucker				4		1	1	2	8	1
freshwater drum									0	0
brown bullhead									0	0
lake chub									0	0
yellow perch									0	0
white perch									0	0
white bass									0	0
gizzard shad									0	0
smallmouth bass									0	0
longnose sucker									0	0
Site Totals	8	43	66	33	34	3	10	16	213	26.625
									Session Total	

APPENDIX 1 C

DARLINGTON GILLNET CATCH - JULY 11, 1984 (SURFACE NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife	21	16	17	29					83	20.75
smelt		1	9	13					23	5.75
round whitefish									0	0
lake whitefish									0	0
lake trout	1			2					4	1
brown trout		1							1	0.25
rainbow trout	1								1	0
coho salmon									0	0
chinook salmon									0	0
white sucker				1					1	0.25
redhorse sucker									0	0
freshwater drum									0	0
brown bullhead									0	0
lake chub									0	0
yellow perch									0	0
white perch									0	0
white bass									0	0
gizzard shad									0	0
smallmouth bass									0	0
longnose sucker									0	0
Site Totals	23	18	26	45	0	0	0	0	112	28
									Session Total	

* = sites not fished

APPENDIX 1 D

DARLINGTON GILLNET CATCH - JULY 13, 1984
(SURFACE NETS)

SPECIES	Site A *	Site B *	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife			143	225	153	149	56	133	859	143.16
smelt			6	4		3		1	14	2.33
round whitefish									0	0
lake whitefish									0	0
lake trout									0	0
brown trout									0	0
rainbow trout			6	2	3		1	1	13	2.16
coho salmon									0	0
chinook salmon									0	0
white sucker									0	0
redhorse sucker									0	0
freshwater drum									0	0
brown bullhead									0	0
lake chub									0	0
yellow perch									0	0
white perch									0	0
white bass									0	0
gizzard shad									0	0
smallmouth bass									0	0
longnose sucker									0	0
Site Totals	0	0	155	231	156	152	57	135	886	147.67
									Session Total	

* = not fished

APPENDIX 1 E

DARLINGTON GILLNET CATCH - JULY 25, 1984
(BOTTOM NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife	3	9	414	257	651	454	1177	238	3203	400.37
smelt	1						2		3	0.37
round whitefish			1		1		1	2	5	0.62
lake whitefish									0	0
lake trout	1	1	5	2	3	3	2	5	22	2.75
brown trout									0	0
rainbow trout									0	0
coho salmon								1	1	0.12
chinook salmon									0	0
white sucker	5	3		1	1	3	6	9	28	3.50
redhorse sucker									0	0
freshwater drum									0	0
brown bullhead									0	0
lake chub									0	0
yellow perch							2		2	0.25
white perch									0	0
white bass									0	0
gizzard shad									0	0
smallmouth bass									0	0
longnose sucker									0	0
Site Totals	10	13	420	260	656	460	1190	255	3264	408
									Session Total	

APPENDIX 1 F
DARLINGTON GILLNET CATCH - JULY 26, 1984
(SURFACE NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife	294	55	106	78	143	115	321	546	1658	207.25
smelt						1			1	0.12
round whitefish									0	0
lake whitefish									0	0
lake trout	1						1		2	0.25
brown trout							1		1	0.12
rainbow trout									0	0
coho salmon									2	0.25
chinook salmon				1					0	0
white sucker									0	0
redhorse sucker									2	0.25
freshwater drum									0	0
brown bullhead									0	0
lake chub									0	0
yellow perch									0	0
white perch									0	0
white bass									0	0
gizzard shad									0	0
smallmouth bass									0	0
longnose sucker									0	0
Site Totals	295	55	106	79	144	116	323	546	1664	208
									Session Total	

APPENDIX 1 G
DARLINGTON GILLNET CATCH - OCTOBER 16, 1984
(BOTTOM NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife	56	42	49	26	4	5	38	44	264	33
seelt	3			2	1	1			6	0.75
round whitefish	2	1	1	2					7	0.87
lake whitefish									0	0
lake trout	2		1		3	1	5	11	23	2.87
brown trout	2			4	2		4	2	14	1.75
rainbow trout								1	1	0.12
coho salmon									0	0
chinook salmon	2	1	1	1	1		16	3	26	3.25
white sucker	1								1	0.12
redhorse sucker	1	1	1	3		1		2	27	3.37
freshwater drum	19	6	5				7	3	11	1.37
brown bullhead			1						1	1.37
lake chub									1	0.12
yellow perch	1		1						1	0.12
white perch				1				2	4	0.50
white bass							1		1	0.12
gizzard shad		1							1	0
smallmouth bass									0	
longnose sucker									0	
Site Totals	89	52	60	39	11	9	71	68	399	49.87
									Session Total	

APPENDIX 1 H
DARLINGTON GILLNET CATCH - OCTOBER 23, 1984
(BOTTOM NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife	31	152	154	103	133	64	219	155	1011	126.37
smelt	1	7	4	6	1		18	30	67	8.37
round whitefish		7	2	4	1	3	4		21	2.62
lake whitefish			1						1	0.12
lake trout	1	2		2	1	1			7	0.87
brown trout							1	1	2	0.25
rainbow trout			1	1					2	0.25
coho salmon									0	0
chinook salmon									0	0
white sucker	1	9	2	3		3	4	8	30	3.75
redhorse sucker					1	1		1	3	0.37
freshwater drum					1	1		2	3	0.37
brown bullhead	1				5	4			10	1.25
lake chub		3	1		1				5	0.62
yellow perch					1		1		2	0.25
white bass		1			1	1			2	0.25
gizzard shad		1							2	0.25
smallmouth bass									0	0
longnose sucker									0	0
Site Totals	34	174	172	118	149	77	247	197	1168 Session Total	146

APPENDIX 1 I

DARLINGTON GILLNET CATCH - OCTOBER 24, 1984
(SURFACE NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife	227	24	23	5	33	18	66		396	49.50
smelt	1				1		3		5	0.62
round whitefish									0	0
lake whitefish									0	0
lake trout						1			2	0.25
brown trout	3	3	1	1	7	3			18	2.25
rainbow trout	5	5	5		2	1	3	3	24	3.00
coho salmon							4	4	8	1.00
chinook salmon									0	0
white sucker									0	0
redhorse sucker							1		1	0.12
freshwater drum									0	0
brown bullhead									0	0
lake chub									0	0
yellow perch									0	0
white perch									0	0
white bass									0	0
gizzard shad	1								1	0.12
smallmouth bass									0	0
longnose sucker									0	0
Site Totals	237	32	30	6	43	23	77	7	455	56.87
									Session Total	

APPENDIX 1 J

DARLINGTON GILLNET CATCH - OCTOBER 25, 1984
(SURFACE NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife	41	8	8	9	5		13		84	10.50
smelt	2	1			1		3		7	0.87
round whitefish									0	0
lake whitefish									0	0
lake trout	2						1		3	0.37
brown trout	7	1	2		2		1	2	15	1.87
rainbow trout	3	4	2		6			2	17	2.12
coho salmon	3	3	4	4	4		2	2	22	2.75
chinook salmon									0	0
white sucker									0	0
redhorse sucker									0	0
freshwater drum									0	0
brown bullhead									0	0
lake chub									0	0
yellow perch									0	0
white perch									0	0
white bass							1		1	0.12
gizzard shad									0	0
smallmouth bass									0	0
longnose sucker									0	0
Site Totals	58	17	16	13	18	0	21	6	149	18.62
									Session Total	

APPENDIX 1 K

DARLINGTON GILLNET CATCH - NOVEMBER 6, 1984
(SURFACE NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife						2	11	4	17	2.12
smelt									0	0
round whitefish									0	0
lake whitefish									0	0
lake trout		1	3	5		4	5	4	22	2.75
brown trout	1		6	2	1	4	3	5	22	2.75
rainbow trout	9				7	3	3	5	27	3.37
coho salmon	1		1				1	1	4	0.50
chinook salmon				1					1	0.12
white sucker		1							1	0.12
redhorse sucker									0	0
freshwater drum									0	0
brown bullhead									0	0
lake chub									0	0
yellow perch									0	0
white perch									0	0
white bass									0	0
gizzard shad									0	0
smallmouth bass									0	0
longnose sucker									0	0
Site Totals	11	2	10	8	8	13	23	19	94	11.75
									Session Total	

APPENDIX 1 L

DARLINGTON GILLNET CATCH - NOVEMBER 7, 1984
(BOTTOM NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife	4	5		1	1	3	28	31	73	9.12
saelt		1							1	0.12
round whitefish	10	7	2	2	2	1	17	8	49	6.12
lake whitefish									0	0
lake trout	1	5	7	1	3	1	1	2	21	2.62
brown trout	1				2		6	4	13	1.62
rainbow trout							1		1	0.12
coho salmon									0	0
chinook salmon								1	1	0.12
white sucker	2		3	1			1	1	8	1
redhorse sucker									0	0
freshwater druse									0	0
brown bullhead									0	0
lake chub		3					1		4	0.50
yellow perch									0	0
white perch									0	0
white bass						1			1	0.12
gizzard shad									0	0
sealimouth bass									0	0
longnose sucker									0	0
Site Totals	18	21	12	5	8	6	55	47	172	21.5
									Session Total	

APPENDIX 1 M

DARLINGTON GILLNET CATCH - NOVEMBER 20, 1984
(SURFACE NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife		4	1		3				8	1.00
seelt									0	0
round whitefish									0	0
lake whitefish									0	0
lake trout	1	1		1	1	5		1	10	1.25
brown trout			1	1	4	3	1	4	14	1.75
rainbow trout	2			1	4	2	2		11	1.37
coho salmon				1	1	3	1		6	0.75
chinook salmon									1	0.12
white sucker									0	0
redhorse sucker									0	0
freshwater drum									0	0
brown bullhead									0	0
lake chub									0	0
yellow perch									0	0
white perch									0	0
white bass									0	0
gizzard shad									0	0
seamouth bass									0	0
longnose sucker									0	0
Site Totals	3	5	2	4	13	13	5	5	50	6.25
									Session Total	

APPENDIX 1 N

DARLINGTON GILLNET CATCH - NOVEMBER 21, 1984
(BOTTOM NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife	7	3				1	3	3	17	2.12
seelt									0	0
round whitefish	1	4	2		2	1	7	9	26	3.25
lake whitefish									0	0
lake trout		11	1	1		1	6	16	36	4.50
brown trout	1				2	2	2	2	9	1.12
rainbow trout									0	0
coho salmon	1								1	0.12
chinook salmon									0	0
white sucker	1				3	4		1	9	1.12
redhorse sucker									0	0
freshwater druse									0	0
brown bullhead									0	0
lake chub	1				1				2	0.25
yellow perch									0	0
white perch									0	0
white bass					1		1	1	3	0.37
gizzard shad									0	0
sealemouth bass									0	0
longnose sucker									0	0
Site Totals	12	18	3	1	9	9	19	32	103	12.87
									Session Total	

APPENDIX 10

DARLINGTON GILLNET CATCH - DECEMBER 11, 1984
(BOTTOM NETS)

SPECIES	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Total	Fish/net
alewife									0	0
saelt									0	0
round whitefish	36	9	9	3	25	10	6	11	109	13.62
lake whitefish					1				1	0.12
lake trout	1								1	0.12
brown trout	1	3	2		2	1		1	10	1.25
rainbow trout								1	1	0.12
coho salmon									0	0
chinook salmon									0	0
white sucker			1	2	3	1	5	5	17	2.12
redhorse sucker									0	0
freshwater drum									0	0
brown bullhead									0	0
lake chub	3								3	0.37
yellow perch	1						1		2	0.25
white perch									0	0
white bass					2	2			4	0.50
gizzard shad									0	0
smallmouth bass									0	0
longnose sucker									0	0
Site Totals	42	12	12	5	33	14	12	18	148	18.5
									Session Total	

APPENDIX 2 A

DARLINGTON ROUND WHITEFISH MERISTIC DATA - 1984

Fish #	Date	Fork Length (mm)	Weight (g)	Age (Yrs)	Fish #	Date	Fork Length (mm)	Weight (g)	Age (Yrs)
001	04/05/84	370	500	4+	048	07/11/84	436	925	5
002	04/05/84	305	250	3+	049	07/11/84	396	700	5
003	04/05/84	335	350	3+	050	07/11/84	390	700	5+
004	04/05/84	390	800	6	051	07/11/84	212	100	2+
005	10/07/84	373	480	5	052	07/11/84	206	100	2+
006	25/07/84	331	400	4	053	07/11/84	416	900	5+
007	25/07/84	385	560	5+	054	07/11/84	399	750	5
008	16/10/84	575	1500	6	055	07/11/84	326	350	3+
009	16/10/84	420	650	5+	056	07/11/84	338	400	3+
010	16/10/84	390	900	5+	057	07/11/84	353	450	4+
011	16/10/84	405	850	6	058	07/11/84	384	650	4+
012	16/10/84	380	700	5	059	07/11/84	360	450	4+
013	16/10/84	415	800	6+	060	07/11/84	380	650	4+
014	23/10/84	425	790	7	061	07/11/84	356	550	4+
015	23/10/84	352	500	4+	062	07/11/84	395	650	4+
016	23/10/84	400	660	5+	063	07/11/84	433	870	6+
017	23/10/84	380	830	4+	064	07/11/84	405	810	4+
018	23/10/84	300	260	3+	065	07/11/84	367	505	4+
019	23/10/84	410	860	5	066	06/11/84	421	810	5+
020	23/10/84	405	815	5+	067	06/11/84	408	800	5+
021	23/10/84	375	600	5	068	06/11/84	416	916	5+
022	23/10/84	405	800	5+	069	06/11/84	412	900	6
023	23/10/84	300	290	3+	070	06/11/84	398	790	5
024	23/10/84	320	390	3+	071	06/11/84	402	790	6+
025	23/10/84	405	720	5+	072	06/11/84	390	620	4+
026	23/10/84	345	480	4+	073	21/11/84	395	800	5+
027	23/10/84	375	600	4+	074	21/11/84	425	975	6+
028	23/10/84	465	1200	7+	075	21/11/84	350	525	3+
029	23/10/84	410	910	4+	076	21/11/84	390	750	5
030	23/10/84	390	630	5+	077	21/11/84	380	675	4+
031	23/10/84	413	790	6+	078	21/11/84	450	1250	6+
032	23/10/84	410	890	5+	079	21/11/84	385	775	5
033	23/10/84	405	730	6	080	21/11/84	390	740	5+
034	23/10/84	556	2430	7	081	21/11/84	425	900	6
035	23/10/84	337	425	3+	082	21/11/84	350	490	4+
036	23/10/84	345	440	4+	083	21/11/84	415	900	6
037	23/10/84	405	790	5+	084	21/11/84	405	700	6+
038	07/11/84	410	700	6	085	21/11/84	450	1210	7+
039	07/11/84	416	820	6+	086	21/11/84	240	175	2+
040	07/11/84	332	380	3+	087	21/11/84	410	825	6
041	07/11/84	320	320	3+	088	21/11/84	460	1350	8+
042	07/11/84	366	600	4+	089	21/11/84	365	650	4+
043	07/11/84	344	560	4+	090	21/11/84	390	775	4+
044	07/11/84	342	420	3+	091	21/11/84	370	590	4+
045	07/11/84	421	880	5	092	21/11/84	340	425	4+
046	07/11/84	392	780	6+	093	21/11/84	410	800	6
047	07/11/84	426	875	6	094	21/11/84	420	900	4+

APPENDIX 2 A CONTINUED
DARLINGTON ROUND WHITEFISH MERISTIC DATA - 1984

Fish #	Date	Fork Length (mm)	Weight (g)	Age (Yrs)	Fish #	Date	Fork Length (mm)	Weight (g)	Age (Yrs)
095	21/11/84	400	750	6+	142	11/12/84	406	800	6+
096	21/11/84	435	1150	6+	143	11/12/84	373	700	4+
097	21/11/84	460	1220	7+	144	11/12/84	352	525	4+
098	21/11/84	310	350	3+	145	11/12/84	336	475	3+
099	21/11/84	390	700	6	146	11/12/84	359	575	3+
100	11/12/84	327	400	3+	147	11/12/84	397	825	5+
101	11/12/84	416	850	6+	148	11/12/84	410	775	6
102	11/12/84	435	910	6+	149	11/12/84	435	1140	7+
103	11/12/84	450	920	7+	150	11/12/84	310	360	3+
104	11/12/84	452	1120	7+	151	11/12/84	325	380	3+
105	11/12/84	385	680	5+	152	11/12/84	375	690	5+
106	11/12/84	438	1020	7+	153	11/12/84	405	780	6+
107	11/12/84	374	560	5+	154	11/12/84	372	640	5
108	11/12/84	379	630	4+	155	11/12/84	415	850	6
109	11/12/84	383	690	4+	156	11/12/84	390	840	6+
110	11/12/84	400	965	7	157	11/12/84	445	1100	8+
111	11/12/84	415	850	5+	158	11/12/84	390	740	5+
112	11/12/84	388	650	5+	159	11/12/84	425	920	5+
113	11/12/84	404	770	5+	160	11/12/84	350	675	5+
114	11/12/84	362	600	4+	161	11/12/84	395	760	6+
115	11/12/84	454	1250	8	162	11/12/84	350	450	3+
116	11/12/84	370	690	5+	163	11/12/84	350	450	4
117	11/12/84	395	690	5+	164	11/12/84	320	380	3+
118	11/12/84	410	875	5+	165	11/12/84	365	585	4+
119	11/12/84	417	830	5+	166	11/12/84	390	700	5+
120	11/12/84	390	725	5+	167	11/12/84	335	450	4+
121	11/12/84	450	1100	7+	168	11/12/84	400	825	6+
122	11/12/84	380	650	4+	169	11/12/84	440	1150	8+
123	11/12/84	455	450	3+	170	11/12/84	370	600	5+
124	11/12/84	400	725	4+	171	11/12/84	350	500	4
125	11/12/84	395	690	5+	172	11/12/84	328	450	3+
126	11/12/84	410	800	5+	173	11/12/84	475	1425	7+
127	11/12/84	465	1280	7	174	11/12/84	414	925	5+
128	11/12/84	380	750	5+	175	11/12/84	400	825	5+
129	11/12/84	425	950	6+	176	11/12/84	395	740	6+
130	11/12/84	445	1050	8	177	11/12/84	430	975	6+
131	11/12/84	380	650	4+	178	11/12/84	400	800	5
132	11/12/84	365	550	4+	179	11/12/84	415	830	6+
133	11/12/84	428	1000	5+	180	11/12/84	410	900	5+
134	11/12/84	335	460	3+	181	11/12/84	405	900	6
135	11/12/84	410	775	5+	182	11/12/84	460	1190	7+
136	11/12/84	315	400	3+	183	11/12/84	460	1250	7+
137	11/12/84	375	650	5+	184	11/12/84	430	1130	7+
138	11/12/84	325	400	3+	185	11/12/84	389	700	5
139	11/12/84	445	1100	7+	186	11/12/84	387	530	5+
140	11/12/84	410	880	6	187	11/12/84	507	1775	9
141	11/12/84	437	1025	9	188	11/12/84	417	875	6+

APPENDIX 2 A CONTINUED

DARLINGTON ROUND WHITEFISH MERISTIC DATA - 1984

Fish #	Date	Fork Length (mm)	Weight (g)	Age (Yrs)
189	11/12/84	367	625	5+
190	11/12/84	357	620	4+
191	11/12/84	464	1420	8+
192	11/12/84	462	1425	6+
193	11/12/84	415	1000	6+
194	11/12/84	445	1265	7+
195	11/12/84	390	730	5+
196	11/12/84	435	975	7
197	11/12/84	395	790	6
198	11/12/84	370	610	4+
199	11/12/84	340	450	3+
200	11/12/84	390	760	regenerated
201	11/12/84	376	550	4+

APPENDIX 2 B

DARLINGTON ROUND WHITEFISH FECUNDITY DATA - 11/12/84

Fish #	Fork Length (mm)	Weight (g)	Age (Yrs)	Fecundity (Eggs/female)
173	475	1425	7+	9899
174	414	925	5+	6416
175	400	825	5+	5863
176	395	740	6+	7962
177	430	975	6+	6952
178	400	800	5	6060
179	415	830	6+	8763
180	410	900	5+	9526
181	405	900	6	5932
182	460	1190	7+	14238
183	460	1250	7+	13259
184	430	1130	7+	12223
185	389	700	5	9295
186	387	530	5+	2940
187	507	1775	9	19011
188	417	875	6+	8372
189	367	625	5+	5845
190	357	620	4+	5845
191	464	1420	8+	18748
192	462	1425	6+	20828
193	415	1000	6+	10477
194	445	1265	7+	21437
195	390	730	5+	7841
196	435	975	7	10207
197	395	790	6	8195

Replicate Subsamples:

Fish #	Sample 1	Sample 2	Sample 3	Mean
173	9907	9907	9983	9899
184	12219	12183	12267	12223

APPENDIX 2 C

DARLINGTON ROUND WHITEFISH FECUNDITY: ANALYSIS

Regressions & Correlation Coefficients:

1. Untransformed Data: $Y = A + bX$

Parameters:	A	b	r
Fecundity vs Fork Length (cm)	-35639.6	1090.01	0.77306
Fecundity vs Weight (g)	-3436.26	13.8929	0.84153
Fecundity vs Age (years+)	-9278.05	3232.38	0.72778

2. Transformed Data: $\log Y = A + b(\log X)$

Parameters:	A	b	r
Fecundity vs Fork Length (cm)	-3.11199	4.36014	0.77051
Fecundity vs Weight (g)	-.057819	1.35200	0.85358
Fecundity vs Age (years+)	2.50245	1.88791	0.73338

APPENDIX 3 A

DARLINGTON SUBSTRATE MONITORING SITES - 1984

Site #	Latitude (°-'-")	Longitude (°-'-")	Loran - C Coordinates	Depth (meters)
S1	43 51 50	78 44 00	16157.7 59339.1	6.5
S2	43 51 45	78 44 00	16158.2 59337.8	8.0
S3	43 51 35	78 44 00	16159.0 59337.9	10.0
S4	43 51 35	78 44 20	16159.0 59336.2	10.5
S5	43 51 35	78 44 25	16159.0 59335.5	11.5
S6	43 51 35	78 44 25	16159.1 59335.2	11.0
S7	43 51 35	78 44 25	16159.2 59334.7	11.5
S8	43 51 35	78 44 25	16159.2 59334.6	11.0
S9	43 51 25	78 44 30	16160.8 59334.0	10.5
S10	43 51 20	78 44 35	16161.5 59332.5	11.5
S11	43 51 35	78 44 45	16159.6 59332.1	10.0
S12	43 51 35	78 43 50	16158.8 59341.1	9.0

APPENDIX 3 B

DARLINGTON SUBSTRATE MONITORING SITES - VISUAL ESTIMATES OF SUBSTRATE COMPOSITION

Site #	Oct 4/84	Nov 30/84	Sept 11/85	Comments
S1	25% boulder 60% cobble 5% pebble 10% clay/sand	60% boulder 40% cobble	30% boulder 55% cobble 15% clay	2-5 cm algae on rocks, 40% coverage (Oct Nov/84)
S2	40% boulder 20% cobble 15% clay 25% sand	75% boulder 5% cobble 20% sand	80% boulder 20% sand	sand ridges 25 cm spacing 10 cm high. sand/clay patches
S3	75% sand 15% cobble 5% boulder 5% clay	70% sand 20% boulder 10% cobble	not sampled due to intake construction	sand ridges 25-30 cm spacing, 8-10 cm high
S4	25% boulder 30% cobble 30% gravel 15% clay	35% boulder 35% cobble 30% clay	10% boulder 80% cobble 10% clay	exposed clay patches up to 3m x 6m
S5	15% boulder 35% cobble 50% gravel	20% boulder 60% cobble 20% gravel	25% boulder 30% cobble 10% gravel 5% sand 30% bedrock	algae 3-4 cm on rocks, 40% coverage. gravel/cobble sizes similar
S6	40% boulder 30% cobble 20% gravel 10% clay	40% boulder 30% cobble 20% clay 10% sand	60% boulder 30% cobble 10% bedrock	algae 40% coverage. clay patches .5m x 1m
S7	40% boulder 30% cobble 10% gravel 20% clay	40% boulder 40% cobble 15% clay 5% sand	60% boulder 30% cobble 10% bedrock	construction disturbance (diffuser)
S8	30% boulder 30% cobble 30% gravel 8% clay 2% sand	10% boulder 70% cobble 15% clay 5% sand	40% boulder 40% cobble 20% gravel	clay smooth & hard. little algae (Nov)

APPENDIX 3 B CONTINUED

S9	15% boulder 40% cobble 40% gravel 5% clay	10% boulder 80% cobble 10% gravel	10% boulder 30% cobble 40% gravel 20% clay	3 cm algae 15% coverage (Oct/84)
S10	15% boulder 35% cobble 35% gravel 10% clay 5% sand	15% boulder 70% cobble 10% gravel 5% sand	50% cobble 40% pebble 10% sand	3 cm algae 40% coverage (Nov/84)
S11	Not Sampled	40% boulder 40% cobble 10% sand 10% clay	50% boulder 50% cobble	3 cm algae 40% coverage. sand between rocks
S12	Not Sampled	20% boulder 80% cobble	10% boulder 90% cobble	2 cm algae 40% coverage (Nov/84)

DISTRIBUTION

Mr. C.W. Dawson (20)
Dr. D. Mills
Dr. A.E. Christie
Mr. G.T. Haymes
Mrs. R. Nakrosius
Dr. J.S. Griffiths (3)

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